Ranking of Nations and Heightened Competition in Matthew Core Journals: Two Faces of the Matthew Effect for Countries

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ABSTRACT

THE MATTHEW EFFECT FOR COUNTRIES (MEC) consists of the systematic deviation in the number of actual (observed) citations from the number of expected citations: A few countries, expecting a high impact (i.e., a high number of cites per paper) receive a surplus of citations, while the majority of countries, expecting a lower impact, lose citations.

The MEC is characterized by numerous facets, but two are the most impressive. The first is the possibility of ranking the science nations by their overall efficiency of scientific performance, thus making the MEC attractive for science policy. The second is the concentration of the MEC in a small number of scientific journals which happen to be the most competitive markets for scientific papers and, therefore, are of interest to librarians as well as scientists.

First, by using an appropriate measure for the above-mentioned deviation of the observed from the expected citation rate one can bring the countries under investigation into a rank order, which is almost stable over time and independent of the main scientific fields and the size (i.e., publication output) of the participating countries. Metaphorically speaking, this country rank distribution shows the extent to which a country is using its scientific talents. This is the first facet of the MEC.

The second facet appears when one studies the mechanism (i.e., microstructure) of the MEC. Every journal contributes to the MEC. The "atoms" of the MEC are redistributed citations, whose number turns out to be a new and sensitive indicator for any scientific journal. Bringing the journals into a rank order according to this indicator, one finds that only 144 journals out of 2,712 contain half of all redistributed citations, and thus

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account for half of the MEC. We give a list of these "Matthew core journals" (MCJ) together with a new typology relating the new indicator to the well-known ones, such as publication or citation numbers. It is our hypothesis that the MCJ are forums of the fiercest competition in science—the "Olympic games in science" proceed in this highest class of scientific journals.

INTRODUCTION

The Discovery of the Matthew Effect for Countries

It is often regretted that research papers, especially in the natural sciences, follow the stereotyped approach "introduction-method-results-conclusions," while the circumstances under which the authors achieved their results remain hidden. In contrast, this paper starts with a historical survey of the research lines we have followed since 1990. Impatient readers may skip this introductory section.

The effect was detected in 1994. A eureka moment of the kind known from discoveries in the natural sciences encouraged us to call what we could see on the computer screen "Matthew effect"— later, more precisely, "Matthew effect for countries" (MEC) (Bonitz, Bruckner, & Scharnhorst, 1995a). This event was no accident, it was preceded by long years of investigations into the structure of national science systems (Bonitz, Bruckner, & Scharnhorst, 1991, 1992, 1993). For instance, a hypothesis of the existence of two worlds in science—a "Right World" and a "Left World"—was a forerunner of the MEC (Bonitz, Bruckner, & Scharnhorst, 1995a, 1995b, 1996a, 1996b). Furthermore, if we hadn't had in the backs of our minds that there was a "Matthew effect in science," as introduced by the eminent scholar R. K. Merton into the sociology of science (Merton, 1968), we never would have dared name our phenomenon "Matthew effect."

In the first phase of our investigations, we studied the effect's time-stability, field-dependency, and its order of magnitude. The effect turned out to be stable over time, independent of scientific fields, and to have a small order of magnitude (Bonitz, Bruckner, & Scharnhorst, 1997). It is not an artifact. At this time, any speculations concerning the practical impact of our findings were beyond the scope of our considerations. Then, a measure for the effect was developed—"Matthew-Index"—the value of which must be computed for each country (Bonitz, Bruckner, & Scharnhorst, 1999a). Countries can be ranked according to this measure, and one can easily see how a certain country is affected by the MEC. We found our country ranking method more expressive than a relational charts representation developed by other researchers (Braun, Glänzel, & Schubert, 1989).

At the beginning, we were taking for granted the public understanding of the Gospel parable described in St. Matthew 25:14–30, and of Merton's Matthew effect in science. We declared, that the Right World (citation rich) countries were "taking away" citations from the Left World

(citation poor) countries (Bonitz, Bruckner, & Scharnhorst, 1995a). It was some time before we grasped the very essence of the famous Biblical parable and then found it surprisingly compatible with our findings (Bonitz, 1997). This fact helped us in treating the "meaning" of the country rank distribution. It enabled us to understand whether it reflects a "discrimination against certain countries," the "quality of national science systems," the "usage of scientific talents," or the "efficiency of competition in science."

Next, we looked for the mechanisms underlying the country rank distribution for the "microstructure of the MEC." It became clear that we had to shift from the "country side" of the MEC to its "journal side." All of the nearly 3,000 journals in the database were expected to (more or less) contribute to the MEC. It seemed evident that the journals are like molecules—molecules that combine to produce the entity we call the MEC. We could not, however, presuppose that these molecules themselves are composed of different sorts of "atoms" (i.e., citations given to the journals), and that only one of these sorts is responsible for producing the MEC. This special sort, which had never before been described in journal investigations, we called "redistributed citations" or "Matthew citations." Our investigations into the behaviour and the properties of the Matthew citations yielded surprising results. The Matthew citations have a very skewed distribution over all journals: Most of the Matthew citations are concentrated in few journals, with 144 journals containing half of the Matthew citations.

These lucky journals also play a highly distinguished role in scientific communication. We proved this hypothesis by trying to falsify it. However, journal ranking by number of publications, by number of citations, by number of participating countries, and by impact factor, failed to yield journal rank distributions highly correlated with the distribution by Matthew citations. Thus, a special role of the "Matthew core journals" (MCJ), as we called them, seemed to be established.

How should this new type of scientific journal be characterized? The journals with the highest reputation? The most important journals in science? The journals with the highest quality articles? If we would choose one of these features we could easily run into boundary problems by having to distinguish between journals of high and low reputation, between those of high and low importance, between high and low quality papers. The appearance of the Matthew citations offered a new possibility: Our proposal is that the number of Matthew citations in a journal reflects the degree of scientific competition going on within its pages. Those competing are scientists, scientific institutions, and countries in science. MCJ are thus the most competitive markets in science. They mirror the experience of other competitive areas, such as the economy or sports, which supports our metaphor that "the Olympic games in science" proceed in the highest class of scientific journals—in the MCJ. Another metaphorical filiation appears, reaching from the MEC to the treatment of the Parable of Talents in St. Matthew:

Not "the rich are becoming richer and the poor poorer," but those who are most effectively competing, irrespective of the amount of talent entrusted to them, will reach the kingdom of heaven (i.e., science).

The Parable of Talents

The knowledge of the parable's full text helped us to understand the nature of our findings. St. Matthew 25:14–30:

> For the kingdom of heaven is as a man travelling into a far country, who called his own servants, and delivered unto them his goods. And unto one he gave five talents, to another two, and to another one; to every man according to his several ability; and straight way took his journey. Then he that had received the five talents went and traded with the same, and made them other five talents. And likewise he that had received two, he also gained other two. But he that had received one went and digged in the earth, and hid his lord's money. After a long time the lord of those servants cometh, and reckoneth with them. And so he that had received five talents came and brought other five talents, saying, Lord, thou deliveredst unto me five talents; behold, I have gained beside them five talents more. His lord said unto him, Well done, thou good and faithful servant: thou hast been faithful over a few things, I will make thee ruler over many things: enter thou into the joy of thy lord. He also that had received two talents came and said, Lord, thou deliveredst unto me two talents: behold, I have gained two other talents beside them. His lord said unto him, Well done, good and faithful servant; thou hast been faithful over a few things, I will make thee ruler over many things; enter thou into the joy of thy lord. Then he which had received the one talent came and said, Lord, I knew thee that thou art an hard man, reaping where thou hast not sown, and gathering where thou hast not strawed: And I was afraid, and went and hid thy talent in the earth: lo, there thou hast that is thine. His lord answered and said unto him, Thou wicked and slothful servant, thou knewest that I reap where I sowed not, and gather where I have not strawed: Thou oughtest therefore to have put my money to the exchangers, and then at my coming I should have received mine own with usury. Take therefore the talent from him, and give it unto him which hath ten talents. For unto every one that hath shall be given, and he shall have abundance: but from him that has not shall be taken away even that which he hath. And cast ye the unprofitable servant into outer darkness: there shall be weeping and gnashing of teeth. (The Bible, 1993)

It is an open question, whether R. K. Merton, writing his well-known paper "The Matthew effect in science" (Merton, 1968) (see also the next section), had in mind the whole parable or only the verse "For unto every one that hath shall be given, and he shall have abundance: but from him that has not shall be taken away even that which he hath" (Merton, 1999). In actual fact, Merton quoted only this one verse. Thus, the bulk of subsequent papers citing him fully and exclusively relied on it. Everybody was convinced that Merton's experimental data or observations, and so this verse, reflected the "Matthew effect in science." Initially, so did we, the only difference being that we called "our" Matthew effect "Matthew effect for

countries" and could exactly measure it, while our forerunners could not. However, in measuring, we ran into many difficulties—difficulties that were only overcome by understanding the whole Parable of Talents, the essence of which is likely not "the rich are becoming richer, and the poor poorer," but "the employment of your given talents is rewarded, and their neglect punished" (see Figure 1). To better explain, recently and fortunately, we became aware of a "New Living Translation" of the Bible, where Merton's verse is translated in the following way: "To those who use well what they are given, even more will be given, and they will have an abundance. But from those who are unfaithful, even what little they have will be taken away" (St. Matthew 25:29, Holy Bible, 1997).

Merton's Matthew Effect in Science

The material discussed in Merton's insightful paper has so many dimensions, that it could hardly have elaborated its correspondence with a whole Biblical text. Moreover, the story of Merton's Matthew effect in science was not finished with the publication of the "Science" paper in 1968. Twenty years later Merton "updated" it through another insightful paper (The Matthew effect in science, II), in which he included his thoughts about cumulative advantage and the symbolism of intellectual property (Merton, 1988). Thus, by no means could Merton be accused of treating the Matthew matter too simplistically. While he faced the difficulty that he could not measure the phenomena he observed at the microlevel of science (i.e., of the allocation of credit to scientists or scientific institutions), we were lucky, at the macrolevel, to observe a measurable effect. However, to explain what...

Figure 1. "To those who use well what they are given, even more will be given . . . " (Holy Bible, 1997, St. Matthew 25:16). Reprinted with permission of Sadifa Media Verlags GmbH.

we measure and observe, we nevertheless must go down to the microlevel again, and here we participate in the tremendous experience described in Merton's work.

Very often an effect is something that happens against a certain expectation or model underlying this expectation. The effect then disappears when the model is improved; the observation is in accord with the expectation. However, the measurability of the effect is the pre-condition for investigating these interactions. The MEC fulfills this condition. The behaviour of the third servant in the parable deviates from the expected behavior, although his smaller abilities compared to the other servants were already taken into account.

Countries: The First Face of the MEC

A Measure for the MEC: The Matthew-Index

When we construct for each of our forty-four countries a rank distribution plotting the observed value of its "impact" (or "citations per paper"), we achieve a skewed curve. That, however, has nothing to do with the Matthew effect. When we take our forty-four countries in the same rank order and plot for each the expected value of its "impact" (or "expected citations per paper"), we achieve another skewed curve that has also nothing to do with the Matthew effect. When we superimpose the two curves, they do not coincide. Instead, in the region of high impact, the "observed values" are, in most of the rank positions, systematically greater than the "expected values," while in the region of low impact the "observed values" are, in nearly all rank positions, systematically smaller than the "expected values." This effect we call the MEC. We introduce a convenient measure for the deviations—the "Matthew-Index." This measure is positive in cases where the observed values exceed the expected values; it is negative in the opposite cases, when the expected values exceed the observed ones. (For details of the methodology see Appendix A.) When the countries are re-ranked according to the Matthew-Index, one gets Figure 2. In interpreting Figure 2, one should keep in mind that it does not explicitly show that the countries with a gain in citations (from Switzerland to Finland) have higher expectation values, and that the countries with citation losses (from PR China to Belgium) have lower expectation values. Neither does it show that the absolute values of the gains and/or losses may differ significantly from country to country, because the Matthew-Index gives relative values (in percent). For instance, the relative gain of Switzerland may be 14 percent against 7 percent in the case of Germany FR, but the absolute gain of Switzerland is only 2,000 for Switzerland but 4,000 for Germany FR. Likewise the gain of 4,000 citations for Germany (only 7 percent) has a very different impact from the loss of 4,000 citations for India, where it corresponds to –44 percent! Generally, it should be noted, that the size of a country (in publica-

tions) does not play a role in Figure 2: A small country like Sweden can belong to the "winners," and large countries like India or Russia can belong to the "losers."

The Right World and the Left World in Science

A rank order, due to its one-dimensionality, provokes immediate judgement: The top ranked are the "best," all others are not as good. What is the rank number of my own country? Why is it not better? Obviously the method is wrong! Long before seeking explanations for the rank order of Figure 2, we called, for mere convenience, the "winner" countries "Right World countries," and the "loser" countries "Left World countries." The bars for the first point to the right, those for the second, to the left side. Figure 2 seems not to be chaotic; it seems to make sense. Obviously, the countries "going to the right" (see Figure 2) are also on the "right" track. But all these considerations are not an explanation of Figure 2. Even if we say that it reflects the MEC, we have to answer the simple question "What is the Matthew effect?"

We can, however, falsify from the beginning the most frequently generated hypotheses. "The rich are becoming richer, the poor poorer." So Sweden is a rich country in science, and Russia is a poor country? Rich and poor in what respect? Or: "The Left World countries are discriminated against by the Right World countries." So, Denmark discriminates against PR China? Why not the other way round? Or: "The language barrier puts non-English countries into the category of the Left World countries." But why does India belong to this category? No doubt, there may be a component of discrimination, there may be a language barrier, but how essential are these and numerous other components we could think of, cultural, historical, geographical, economical, and political ones?

Our method is based on the Science Citation Index (SCI). If we consider the citing authors as experts in their fields, the SCI turns out to be the largest expert system of the world (Bonitz, 1990). This unique property of the SCI guarantees its high reliability when it is used, as in our case, for studies at a high macrolevel of science. Any hypothesis of a systematic discrimination of countries would be, therefore, a hypothesis against the whole community of scientists.

We knew that a well-founded explanation of the MEC could be achieved only when the micromechanisms underlying were investigated and understood. This is the task of the next section. However, we present here, in part, the conclusions of that section. After discovery of the "atoms" of the MEC, and after studying their "meaning" and function, we can conclude: The country rank distribution given in Figure 2 reflects the extent to which a country is using its scientific talents, or better, it reflects the efficiency of competition between the countries participating in the global enterprise "science." The Right World countries generally compete more efficiently

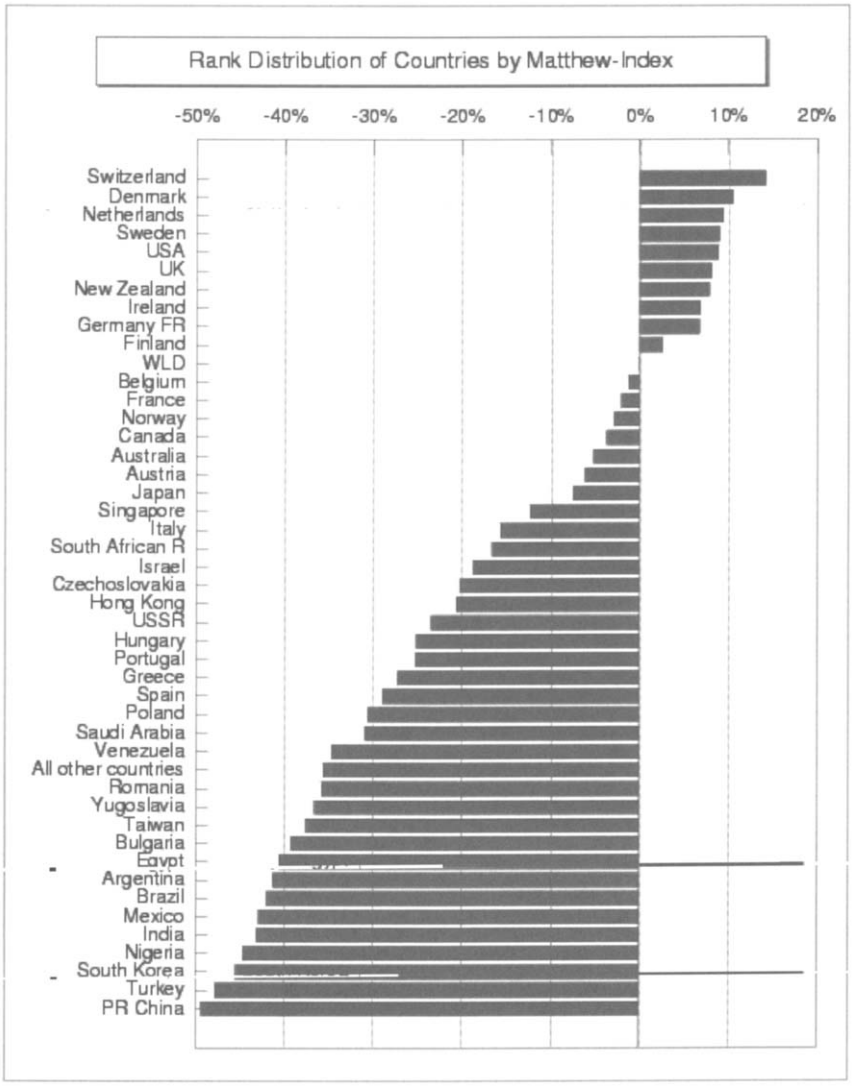

Figure 2. Matthew Effect for Countries. A few countries are gaining surplus citations on a high level of impact, while the majority of countries are losing citations on a low level of impact. Matthew-Index = (obs – exp) ÷ exp [%].

than the Left World countries. This efficiency is lowest for PR China and highest for Switzerland.

Impact on Science Policy

If the rank distribution in Figure 2 actually reflects what we claim it reflects—the national ability for competition in global science—then it should be of interest for science politicians of many countries. A lack of this ability obviously means the waste of national resources (Russia loses a quarter of its expected reward, India more than 40 percent). But improving the ability to compete does not necessarily mean increasing the resources. It can also be achieved by learning from the MEC.

Journals: The Second Face of the MEC

Investigation of the MEC's Microstructure

We mentioned above that the Matthew-Index, according to which the countries are ranked in Figure 2, can be computed for every country, when the numbers of the observed and of the expected citations are known. While the observed citations just have to be counted, the expected citations must be computed. The observed citations can, in principle, stem from any of the 2,712 journals in our journal sample, while the expected citations have to be derived from the numbers of papers in, and the impact factors of, the journals in which the countries publish. For a given journal, the national number of expected citations is exp = (number of national papers) · (journal impact factor). A journal impact factor is, roughly speaking, the number of the citations given in a certain time to all papers in the journal divided by the number of papers. An impact factor of 5 says that an "average" paper receives five citations, while an impact factor of 0.2 requires five articles to attract one citation. The journal impact factor tells how many citations an author can "expect" for his paper, provided it is of average quality. Journals with high impact factor seem to have a higher reputation than journals with low impact factor. For an understanding of what we call the microstructure of the MEC, one must be informed about what is going on in every journal. Some of the fundamentals are demonstrated in the next figure.

The upper graph of Figure 3 shows the national impacts for the journal *Nature*. The impact factor of this journal is 29, because the 7,983 papers received 231,749 citations. However, not a single country achieves 29 citations per average paper—a few countries are getting more than 29, most of the countries get less. Finland, for instance, receives only 5 citations, but Japan receives 38 citations per average paper. This behavior is typical for any scientific journal (with exception of the mono-national journals). There are always countries exceeding the journal impact, and other countries the national impact of which is below the journal impact value. It cannot be predicted whether a certain country in a certain journal will be on the "winning" side or on the "losing" side. The knowledge about the national im-

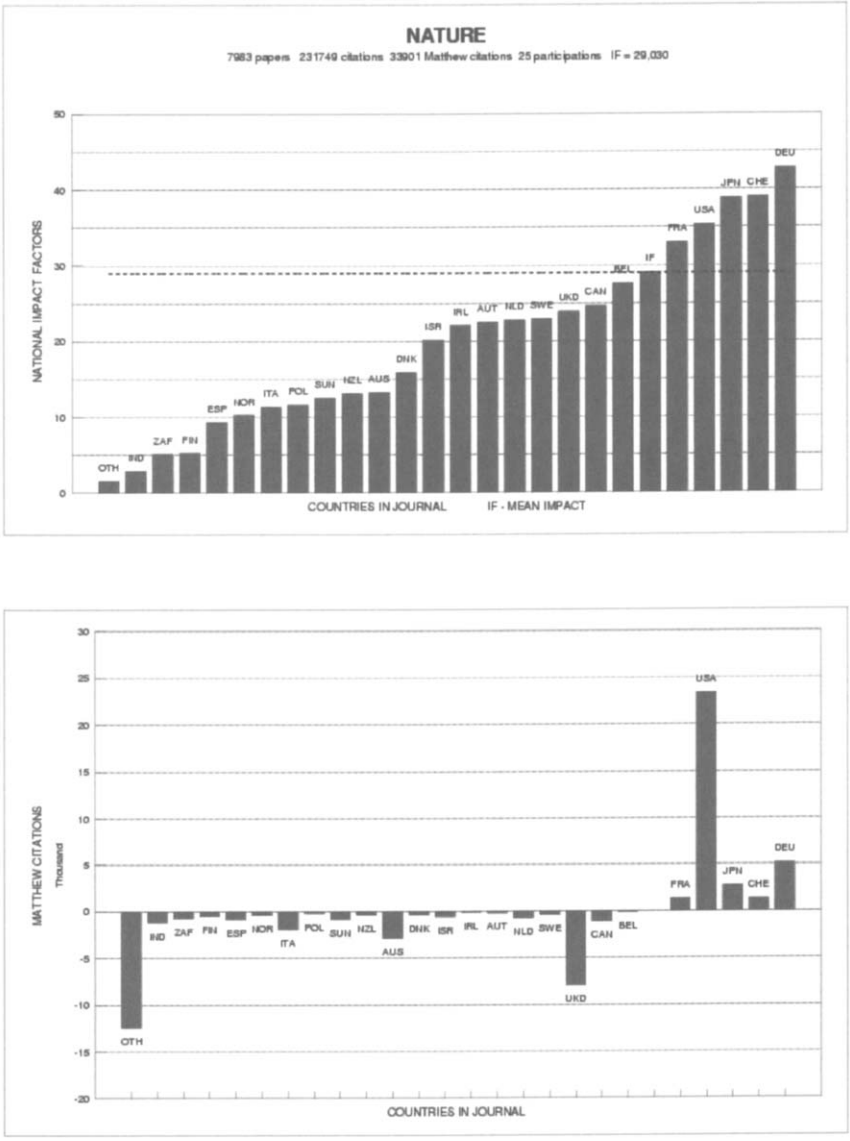

Figure 3. National Impact and Matthew Citations in a Scientific Journal.

pact in a journal could provide useful information for designing a national publication strategy; however, for merely practical reasons the scientific community retains the model of "the same impact factor for all." Comparison of the reality with this model provides new insight. At first, we learn that the MEC has its roots in this model. Second, at the order of magnitude of the deviation, we reach surprising conclusions on the very nature of the journals in science.

The lower graph of Figure 3 represents the countries that publish in *Nature* in the same order, but gives their gain or loss of citations with respect to their national impact factor in absolute numbers. So, the United Kingdom loses about 8,000 citations, while Germany FR gains 5,000. It is important to mention that, by the definition of the journal impact factor, the number of citations lost by the "losing" countries in a journal, is equal to the number of surplus citations gained by the "winning" countries of that journal. It seems to be a consequence of the model of "the same impact factor for all," that this number of citations is redistributed from left to right, from the "loser" to the "gainer" countries. We call these citations "redistributed citations" or "Matthew citations." The journal *Nature* has 33,901 Matthew citations, this number being the difference between the numbers of observed and expected citations on each side. The sign is negative at the left side and positive at the right side. Now we are prepared to understand the "mechanism" leading from the redistribution in the single journals to the MEC at the macrolevel. For every country and for all journals in which this country publishes, one has to sum up the numbers of Matthew citations, taking into account their positive or negative sign.

If the sum is positive, this country will belong to the Right World countries; if the sum is negative, it will belong to the Left World countries. Thus, the MEC is the result of the countrywise summing up of Matthew citations. Whether a country belongs to the "winners" or to the "losers" in a certain journal can by no means be predicted from the country rank distribution in Figure 2. For instance, the USA—a "winner" at the macrolevel—belongs to the "losers" in some journals, while Russia—a "loser" at the macrolevel—is a clear "winner" in certain journals. So one must take into account all journals in order to get the final country ranking of Figure 2.

Matthew Citations: The Atoms of the MEC

We find it appropriate to call the Matthew citations the "atoms of the MEC." Just as the atoms in the physical microworld build up our macroworld, the Matthew citations are responsible for the MEC. Only a small percentage of the citations that are received by a journal's papers are Matthew citations. In the case of *Nature* about 15 percent. How can we detect whether a "normal" citation is also a Matthew citation or not? Of course, there is no way, and there is no need. Matthew citations appear, when we apply the model "the same impact factor for all." They signal that something

more is going on than predicted by that too simple model. Their number can only be computed; no institution in science exists that, as the Lord in the parable, could actually redistribute citations. No simple mechanism is conceivable that produces Figure 3, upper graph, in the case of *Nature*, and quite another graph for the journal *Biochemistry*. The Matthew citations help us to refine our simple model. Moreover, they turn out to be a sensitive indicator for essential processes in the whole system of scientific communication.

Journal Ranking

Journals can be ranked by numerous parameters and indicators. Well-known is the ranking by journal size (number of papers), by recognition (number of achieved citations), by impact (number of citations per paper), or by "internationality" (number of participating countries). Correlations between the different rank distributions have been studied, power laws have been described for the size-recognition dependency. It seems that we know everything about the scientific journal in its proud 335-year history.

However, nobody has ever ranked scientific journals by their atoms of the MEC, by their number of Matthew citations, because this parameter came into being only when the microstructure of the MEC was investigated (Bonitz, Bruckner, & Scharnhorst, 1999b). When the 2,712 journals of our sample are ranked by their numbers of Matthew citations, the top journal is *Nature* (33,901), and the last ranking are 25 journals with zero Matthew citations, though among these 25 are 4 journals with so many papers that they even possess the status of a "publication core journal" (see definition below). The distribution is not linear but extremely skewed: Half of all Matthew citations are concentrated in the 144 first-ranking journals! We call these journals MCJ. So, when the Matthew citations are responsible for the MEC, then the 144 MCJ—only 5 percent of all journals—produce half of the effect.

A New Type of Scientific Journal: The Matthew Core Journal

So many types of scientific journals already exist (based on very different parameters, but also on the different journal functions) that the question is legitimate whether the MCJ can add an essential new feature to the whole picture. When we declare, in accordance with Garfield's saying "A few account for the most" (Garfield, 1977, 1996), that the publication core journals account for half of the size of all journals, or that the citation core journals account for half of the recognition achieved by all journals, and that the participation core journals account for half of the internationality represented by all journals—then we say, of course, that the MCJ account for half of the MEC. But what is the MEC, not in our phenomenological definition, but in its nature? Everyone looking at the list of the MCJ (given in Appendix C) will admit that they are apparently of high "importance." Are they all simultaneously publication, citation, and participation core jour-

nals? No, they are not. This can be shown by a new typology of the scientific journals that includes the "newcomers," the MJC (see Appendix B). This highlights something very specific about science, something that characterizes all scientific journals, but that particularly characterizes the MCJ.

It is our hypothesis that one of the most essential features of science—competition—is reflected in a scientific journal by the citation redistribution phenomenon or the number of Matthew citations, and that the MCJ are, therefore, the most competitive markets in the fields of their scientific papers. When we highlight 5 percent of all journals as the most competitive markets, this cannot mean that the "rest" of 95 percent of the journals should or could be neglected. The editors of these journals and the authors publishing in them must not feel they are being discriminated against or doing a useless job. Every journal has its place and its importance in the system of scientific communication. The many are a necessary condition for the functioning of the few. We think it can be helpful to be reminded of the world of sports. There, competition is one of the essential features, and the success of the best is guaranteed only by the existence of a broad national and international basis for the different teams. The "Olympic games in science" proceed in the highest class of science journals—the MCJ.

Impact on Scientists, Journal Editors, and Librarians

It is always pleasant when one faces an overwhelming crowd of things and is offered a pre-selected core that makes decisions easy. When the core selection is well-founded, it can help to improve the functioning of the whole system of scientific communication. Scientists who have produced excellent results should know the MCJ in their field and try to get published there. In doing so, they create the possibility of garnering many surplus citations, but they also take the risk—due to the high competition—to lose citations, a risk that has its source in an usually high level of expectation. Journal editors also should be aware of the rank position of their journal. If it lies in the core, they can be proud, but they must not be disappointed if not. Our rank distribution of journals reflects competition, but there are plenty of journals fulfilling other important tasks, though they do not act as forums for competition, for instance, review journals. Librarians, who always have the problem of acquiring the best and least expensive journals at the same time, will surely profit from the list of journals ranked by the number of Matthew citations. At least the MCJ should be present in any field represented in the library's journal collection.

Conclusions

The consequences of the newly discovered measurable MEC are twofold. With the help of the Matthew-Index, a country rank distribution can be constructed to reflect how effectively each country is taking part in the competition in science. Half of the atoms of the MEC—the Matthew cita-

tions—produce half of the MEC and are concentrated in forums of the highest competition in science—in the MCJ. Science politicians as well as individual scientists, journal editors, and librarians might find these new results useful for their work.

Acknowledgements

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Appendices

Appendix A. The Data

In accordance with previous papers (Bonitz, Bruckner, & Scharnhorst, 1993, 1997), we study a set of forty-four countries, chosen for being highly productive during a certain period of time. These countries and their abbreviations are: ARG—Argentina; AUS—Australia; AUT—Austria; BEL—Belgium; BGR—Bulgaria; BRA—Brazil; CAN—Canada; CHE—Switzerland; CSR—Czechoslovakia; DEU—Germany FR; DNK—Denmark; EGY—Egypt; ESP—Spain; FIN—Finland; FRA—France; GRE—Greece; HKG—Hong Kong; HUN—Hungary; IND—India; IRL—Ireland; ISR—Israel; ITA—Italy; JPN—Japan; KOR—South Korea; MEX—Mexico; NGA—Nigeria; NDL—Netherlands; NOR—Norway; NZL—New Zealand; POL—Poland; PRC—PR China; PRT—Portugal; ROM—Romania; SAR—Saudi Arabia; SGP—Singapore; SUN—USSR; SWE—Sweden; TUR—Turkey; TWN—Taiwan; UKD—UK; USA—USA; VEN—Venezuela; YUG—Yugoslavia; ZAF—South African R; OTH—Other Countries; WLD—World.

Previous analyses started from 1980. Therefore, for our purposes, we still consider all countries of the former Soviet Union as belonging to a "virtual" common national science system. In this report, the time period from 1990 to 1994 is taken into account. The data were prepared by "Re-

search Association for Science Communication and Information e.V." (RASCI) on the basis of *SCI*. First author count is used for national allocation.

The analysis includes 2,712 journals in this time span. Two additional conditions have been imposed: (1) For consideration, a journal had to appear during all five years, and journals with less than 100 papers in five years were excluded. (2) For each journal, countries with more than 10 papers were considered explicitly; countries with a lower number of papers were merged into a category called "other countries" (OTH). This category also covers the countries outside our sample.

The journal impact factors are computed from the citations given during the five years to the papers published in the same five years. Due to this procedure, the journal impact factors are higher than the journal impact factors computed by the ISI.

Appendix B. A New Typology of Scientific Journals

A journal can be a core journal or a non-core journal relative to the four parameters: Publications (PU), citations (CI), participations (PA), and Matthew citations (MC). For instance, a journal of the type "PUCIPAMC" belongs to the cores of all four types; a journal of the type "CIMC" is a citation core journal and a Matthew core journal, but not a publication core journal and not a participation core journal. So, the absence of the corresponding letters denotes that a journal does not belong to the cores of this type. In our sample of 2,712 journals there are 1,981 journals not belonging to any of the four cores (type "NOCORE").

In Appendix C we present a list exclusively of the MCJ. This list includes the journal type, the journal title, the number of the journal's Matthew citations, the corresponding journal rank, and the journal's impact factor with the corresponding journal rank. For a given type and field, the journals are ranked by descending number of Matthew citations.

Appendix C. The Matthew Core Journals

Journal Type	Journal Title	Matthew Citations	Rank	Impact Factor	Rank
	Multidisciplinary				
PUCIPAMC	NATURE	33901	1	29.0	13
PUCIPAMC	SCIENCE	14271	3	29.2	12
PUCIPAMC	ANNALS OF THE NEW YORK ACADEMY OF SCIENCES	1640	79	2.2	992
	Life Sciences				
PUCIPAMC	JOURNAL OF BIOLOGICAL CHEMISTRY	9559	5	13.2	42
PUCIPAMC	LANCET	7427	8	5.7	206
PUCIPAMC	NEW ENGLAND JOURNAL OF MEDICINE	6502	9	10.8	58

Journal Type	Journal Title	Matthew Citations	Rank	Impact Factor	Rank
PUCIPAMC	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE U.S.A.	6372	11	20.8	26
PUCIPAMC	BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS	5881	13	7.1	125
PUCIPAMC	BIOCHIMICA ET BIOPHYSICA ACTA	5443	15	6.6	144
PUCIPAMC	FEBS LETTERS	5437	16	6.9	130
PUCIPAMC	JOURNAL OF IMMUNOLOGY	4904	20	14.3	38
PUCIPAMC	BIOCHEMICAL JOURNAL	4693	21	7.8	101
PUCIPAMC	NEUROLOGY	4201	24	4.8	287
PUCIPAMC	BLOOD	4116	26	12.1	50
PUCIPAMC	NUCLEIC ACIDS RESEARCH	3889	28	8.5	86
PUCIPAMC	AMERICAN JOURNAL OF PHYSIOLOGY	3730	29	6.8	140
PUCIPAMC	EMBO JOURNAL	3512	31	25.7	18
PUCIPAMC	BIOCHEMISTRY	3463	32	10.2	64
PUCIPAMC	BRITISH MEDICAL JOURNAL	3210	36	2.2	999
PUCIPAMC	BRAIN RESEARCH	2863	38	6.0	180
PUCIPAMC	EUROPEAN JOURNAL OF PHARMACOLOGY	2847	39	6.0	179
PUCIPAMC	JOURNAL OF CLINICAL INVESTIGATION	2843	40	16.0	36
PUCIPAMC	BRITISH JOURNAL OF PHARMACOLOGY	2716	42	8.2	94
PUCIPAMC	CIRCULATION	2585	43	11.2	55
PUCIPAMC	EUROPEAN JOURNAL OF BIOCHEMISTRY	2452	47	6.8	131
PUCIPAMC	NEUROSCIENCE LETTERS	2419	48	4.9	277
PUCIPAMC	JOURNAL OF CELL BIOLOGY	2364	50	23.2	24
PUCIPAMC	ONCOGENE	2204	53	12.8	43
PUCIPAMC	ENDOCRIOLOGY	2172	56	9.8	70
PUCIPAMC	JOURNAL OF MOLECULAR BIOLOGY	2067	58	10.5	63
PUCIPAMC	AMERICAN JOURNAL OF CARDIOLOGY	2015	61	4.4	331
PUCIPAMC	CANCER RESEARCH	1974	62	12.0	51
PUCIPAMC	JOURNAL OF VIROLOGY	1968	64	11.9	53
PUCIPAMC	NEUROSCIENCE	1955	65	8.0	97
PUCIPAMC	AMERICAN REVIEW OF RESPIRATORY DISEASE	1865	69	9.2	76
PUCIPAMC	JOURNAL OF PHYSIOLOGY—LONDON	1793	70	9.5	71
PUCIPAMC	JOURNAL OF INFECTIOUS DISEASES	1786	71	7.9	96
PUCIPAMC	EUROPEAN JOURNAL OF IMMUNOLOGY	1738	73	10.7	60
PUCIPAMC	JOURNAL OF BACTERIOLOGY	1727	75	8.1	96
PUCIPAMC	APPLIED AND ENVIRONMENTAL MICROBIOLOGY	1640	80	5.7	203
PUCIPAMC	JOURNAL OF CLINICAL MICROBIOLOGY	1632	82	6.3	160
PUCIPAMC	JOURNAL OF CLINICAL ENDOCRIOLOGY AND METABOLISM	1629	84	8.3	92

Journal Type	Journal Title	Matthew Citations	Rank	Impact Factor	Rank
PUCIPAMC	TRANSPLANTATION	1567	89	5.6	210
PUCIPAMC	MOLECULAR MICROBIOLOGY	1454	95	8.8	80
PUCIPAMC	JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY	1413	98	8.5	84
PUCIPAMC	JOURNAL OF NEUROCHEMISTRY	1292	107	8.4	88
PUCIPAMC	JOURNAL OF PHARMACOLOGY AND EXPERIMENTAL THERAPEUTICS	1237	113	7.2	122
PUCIPAMC	PLANT PHYSIOLOGY	1196	115	8.4	156
PUCIPAMC	METHODS IN ENZYMOLOGY	1177	118	5.7	199
PUCIPAMC	INFECTION AND IMMUNITY	1166	120	7.0	129
PUCIPAMC	ANTIMICROBIAL AGENTS AND CHEMOTHERAPY	1133	124	6.0	182
PUCIPAMC	GENOMICS	1124	126	9.5	73
	Physics				
PUCIPAMC	PHYSICAL REVIEW B—CONDENSED MATTER	15380	2	5.9	183
PUCIPAMC	PHYSICAL REVIEW LETTERS	10254	4	12.7	44
PUCIPAMC	PHYSICS LETTERS B	7630	6	6.5	148
PUCIPAMC	APPLIED PHYSICS LETTERS	7538	7	6.3	157
PUCIPAMC	JOURNAL OF CHEMICAL PHYSICS	6417	10	6.8	132
PUCIPAMC	PHYSICA C	4978	18	5.2	240
PUCIPAMC	PHYSICAL REVIEW D—PARTICLES AND FIELDS	4951	19	5.1	256
PUCIPAMC	JOURNAL OF APPLIED PHYSICS	4507	22	3.2	609
PUCIPAMC	CHEMICAL PHYSICS LETTERS	4277	23	5.0	264
PUCIPAMC	NUCLEAR PHYSICS B	4168	25	7.3	114
PUCIPAMC	PHYSICAL REVIEW A	4041	27	4.9	281
PUCIPAMC	ASTROPHYSICAL JOURNAL	3262	34	7.2	119
PUCIPAMC	ASTRONOMY AND ASTROPHYSICS	2198	55	4.0	407
	Chemistry				
PUCIPAMC	JOURNAL OF PHYSICAL CHEMISTRY	5679	14	5.7	198
PUCIPAMC	JOURNAL OF THE AMERICAN CHEMICAL SOCIETY	5026	17	10.0	68
PUCIPAMC	TETRAHEDRON LETTERS	3426	33	4.2	359
PUCIPAMC	SURFACE SCIENCE	2925	37	4.3	342
PUCIPAMC	JOURNAL OF CHROMATOGRAPHY	2765	41	3.8	434
PUCIPAMC	JOURNAL OF ORGANIC CHEMISTRY	1869	65	5.4	228
PUCIPAMC	ANALYTICAL CHEMISTRY	1726	76	7.2	118
PUCIPAMC	JOURNAL OF THE CHEMICAL SOCIETY—CHEMICAL COMMUNICATIONS	1466	94	4.4	327
PUCIPAMC	MACROMOLECULES	1353	101	5.0	266

Journal Type	Journal Title	Matthew Citations	Rank	Impact Factor	Rank
	Life Sciences				
PUPAMC	TRANSPLANTATION PROCEEDINGS	2473	46	2.0	1128
PUPAMC	MUTATION RESEARCH	2026	60	4.5	319
PUPAMC	JOURNAL OF UROLOGY	1661	78	3.6	494
PUPAMC	KIDNEY INTERNATIONAL	1624	85	7.0	128
PUPAMC	NEUROSURGERY	1577	88	1.7	1356
PUPAMC	JOURNAL OF GENERAL VIROLOGY	1372	99	7.1	126
PUPAMC	AIDS	1360	100	6.6	143
PUPAMC	IMMUNOLOGY	1308	105	5.8	188
PUPAMC	INTERNATIONAL JOURNAL OF CANCER	1279	109	5.6	207
PUPAMC	BRITISH JOURNAL OF CANCER	1242	112	5.3	237
PUPAMC	CHEST	1233	114	2.3	958
PUPAMC	JOURNAL OF THORACIC AND CARDIOVASCULAR SURGERY	1123	127	3.3	584
PUPAMC	GENE	1109	128	5.0	270
PUPAMC	HEPATOLOGY	1068	132	7.2	120
PUPAMC	BIOCHEMICAL PHARMACOLOGY	1063	135	4.2	353
PUPAMC	FEMS MICROBIOLOGY LETTERS	1026	143	2.6	820
	Physics				
PUPAMC	JOURNAL OF PHYSICS—CONDENSED MATTER	2509	44	2.8	737
PUPAMC	JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS	2401	49	2.4	895
PUPAMC	SOLID STATE COMMUNCIATIONS	2253	52	2.9	696
PUPAMC	PHYSICAL REVIEW C—NUCLEAR PHYSICS	2170	72	3.7	476
PUPAMC	NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A	1636	81	2.3	955
PUPAMC	MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY	1632	83	5.5	220
PUPAMC	GEOPHYSICAL RESEARCH LETTERS	1618	86	4.2	364
PUPAMC	JOURNAL OF MAGNETIC RESONANCE	1536	90	5.5	215
PUPAMC	OPTICS LETTERS	1511	92	4.5	320
PUPAMC	JOURNAL OF CRYSTAL GROWTH	1475	93	3.2	588
PUPAMC	ZEITSCHRIFT FUR PHYSIK C—PARTICLES AND FIELDS	1349	102	4.5	313
PUPAMC	THIN SOLID FILMS	1315	104	2.3	942
PUPAMC	NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION B	1300	106	2.1	1060
PUPAMC	EUROPHYSICS LETTERS	1284	108	4.9	264
PUPAMC	JOURNAL OF PHYSICS B—ATOMIC MOLECULAR AND OPTICAL PHYSICS	1184	117	3.5	520

Journal Type	Journal Title	Matthew Citations	Rank	Impact Factor	Rank
PUPAMC	JOURNAL OF GEOPHYSICAL RESEARCH—ATMOSPHERES	1175	119	5.7	197
PUPAMC	PHYSICA B	1138	122	1.5	1463
PUPAMC	PHYSICS LETTERS A	1095	131	2.3	951
PUPAMC	JOURNAL OF THE CHEMICAL SOCIETY—FARADAY TRANSACTIONS	1067	133	3.4	535
PUPAMC	JOURNAL OF VACUUM SCIENCE & TECHNOLOGY B	1066	134	3.9	417
PUPAMC	NUCLEAR PHYSICS A	1054	137	3.7	454
PUPAMC	IEEE TRANSACTIONS ON MAGNETICS	1041	139	1.6	1425
PUPAMC	JOURNAL OF PHYSICS A—MATHEMATICAL AND GENERAL	1040	140	2.6	817
PUPAMC	PHYSICS OF FLUIDS B—PLASMA PHYSICS	1022	144	3.5	501
	Chemistry				
PUPAMC	TETRAHEDRON	1898	67	3.6	489
PUPAMC	JOURNAL OF ELECTRO-ANALYTICAL CHEMISTRY AND INTERFACIAL ELECTROCHEMISTRY	1432	97	3.9	419
PUPAMC	LANGMUIR	1258	111	4.3	350
PUPAMC	ANALYTICA CHIMICA ACTA	1134	123	3.3	562
	Engineering				
PUPAMC	ELECTRONICS LETTERS	2269	51	2.0	1102
PUPAMC	SCRIPTAMETALLURGICA ET MATERIALIA	1063	136	2.0	1068
PUPAMC	JOURNAL OF THE AMERICAN CERAMIC SOCIETY	1028	142	3.1	638
	Life Sciences				
PUCIMC	JAMA—JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION	6270	12	4.2	357
PUCIMC	CELL	3256	35	72.3	3
PUCIMC	JOURNAL OF EXPERIMENTAL MEDICINE	2203	54	25.6	19
PUCIMC	MOLECULAR AND CELLULAR BIOLOGY	2098	57	17.9	31
PUCIMC	DEVELOPMENT	1734	74	15.1	37
PUCIMC	ANNALS OF INTERNAL MEDICINE	1531	91	7.7	103
PUCIMC	AMERICAN JOURNAL OF PATHOLOGY	1277	110	11.3	54

Journal Type	Journal Title	Matthew Citations	Rank	Impact Factor	Rank
	Chemistry				
PUCIMC	ANGEWANDTE CHEMIE—INTERNATIONAL EDITION IN ENGLISH	1970	63	7.6	107
	Life Sciences				
PUMC	AMERICAN JOURNAL OF PSYCHIATRY	3701	30	3.0	657
PUMC	ARCHIVES OF INTERNAL MEDICINE	2499	45	4.4	332
PUMC	ARCHIVES OF OPHTHALMOLOGY	1442	96	2.6	842
PUMC	OPHTHALMOLOGY	1185	116	3.1	644
PUMC	HYPERTENSION	1105	129	8.3	91
	Life Sciences				
CIMC	FASES JOURNAL	1723	77	20.9	25
CIMC	NEURON	1102	130	31.7	9
	Life Sciences				
PAMC	ANNALS OF NEUROLOGY	1140	121	8.5	85
PAMC	DIABETES CARE	1033	141	4.7	290
	Life Sciences				
MC	IMMUNOLOGY TODAY	2054	59	23.5	23
MC	TRENDS IN PHARMACOLOGICAL SCIENCES	1930	66	24.8	21
MC	BIO-TECHNOLOGY	1610	87	6.1	169
MC	TRENDS IN BIOCHEMICAL SCIENCES	1318	103	24.9	20
MC	JOURNAL OF CLINICAL PSYCHIATRY	1130	125	3.4	553
MC	TRENDS IN GENETICS	1061	138	17.8	32

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