A COMPARISON OF ASTRONOMY IN FIFTEEN MEMBER COUNTRIES OF THE ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Abstract

Various data are collected for 15 member countries of the Organisation for Economic Co-operation and Development (OECD) that have to do with the practising of astronomy: (1) using the report of the Astronomy expert meeting of the Megascience Forum of the OECD, the level of astronomy funding, size of the research communities, relative commitment to ground-based versus space-based astronomy, etc.; (2) from other sources the size of the population, Gross National Product and size of the total research community; (3) from the paper of Schubert *et al.* (1989) data on publication and citation scores of these countries in astronomy and the total research effort (excluding social and economic sciences). Using these data the 15 countries have been ranked on: (1) the relative level of astronomy funding; (2) the relative level of performance in astronomy; (3) the correspondence between funding and performance in astronomy; (4) the relative level of performance of the total science effort; and (5) the performance in astronomy relative to that in all sciences.

The results of this study have been summarized in table 10 below. Other interesting results that can be inferred from the data collected in this paper are: (1) one out of every 75,000 inhabitants of these OECD countries is an astronomical researcher; (2) each citizen of these countries spends on average 2.5$ per year on astronomical research (either from the ground or in space); (3) the average budget per researcher amounts to roughly 200,000$ per annum; (4) the average budget for astronomy amounts to 0.016% of the Gross National Product and of order 1% of the total budget for civilian R & D; (5) an astronomical researcher from these countries produces on average 1.7 papers each year and these papers receive on average ten citations in the first five years; (6) researchers in science (excluding economic and social sciences) make up 0.08% of the population in these countries and one in about 65 of these researchers works in astronomy or astrophysics; (7) most countries spend about one-third of their astronomy

budget on salaries, one-sixth on basic support and half on observing facilities (in a ratio one to two for ground-based versus space).

1 Introduction.

In October 1992 the Astronomy Expert Meeting of the *Megascience Forum* of the Organisation for Economic Co-operation and Development (OECD) met in Tenerife. For that meeting and in the context of the Megascience Forum the participants collected information on data such as the funding of astronomy in their countries, the size of the research communities, relative commitment of ground-based versus space-based astronomy and the investment in national or international Megascience facilities. The report (OECD, 1993) contains among other things tables with quantitative information of the kind indicated.

Themselves these data are interesting, but I felt that it would be also of interest to relate them to other data on the countries. In particular I have collected further information such as the size of the population and the Gross National Product (GNP) on the one hand and publication and citation information for both astronomy and the total science effort on the other. The combination of funding and citation information was examined in order to see to what extent each country's funding level corresponds to its performance (value-for-money).

In what follows I present an analysis of these data. I concentrate on rankings that can be determined for respectively the level of funding in astronomy, the performance measured by the output, the performance of science in general and a comparison between astronomy and the total science effort.

2 Funding of astronomy.

Data are taken from the *Astronomy Report* prepared by the OECD Secretariat following the expert meeting on Tenerife in the context of the OECD Megascience Forum. They generally refer to 1991 and/or 1992. The populations and GNP numbers have been taken from the PC-program PCGLOBE 4.0 (©PC Globe Inc., Tempe, AZ, USA) and refer to 1991. These data are collected in table 1. Without further noting this below budgets and GNP's are always annual ones.

There can be no absolute guarantee on the uniformity of these data. However, the instruction from the OECD secretariat to the participants was quite specific. For the budgets the instruction was to include all costs related to the running of astronomy institutes and university groups for the research effort only, but excluding shared costs such as buildings and grounds, administrative personnel of the universities for general facilities, costs for the educational (teaching) program, etc. Having been a participant myself at the expert meeting, I jugde that the determination has been fairly uniform, except possibly for special employment benefits. Contributions to international organisations such as the astronomy part of the science program of the European Space Agency (ESA), the European Southern Observatory (ESO), etc. and astronomy related budgets of national space agencies as NASA (USA), CNES (France), etc. have been taken in full. I judge the figures to have an accuracy of 10 to 15% on a consistent scale.

One way to check this to some extent is to look at the breakdown between various

Table 1: Population and funding data in OECD countries.

Country	Population (10^6)	IAU Members	Researchers	GNP (G$)	Budget (M$)
Australia	16.9	173	180	211	±40
Belgium	9.9	81	131	152	±20
Canada	26.7	206	213	474	20.5
Denmark	5.1	50	71	92.7	9.2
Finland	5.0	29	87	98.8	28.3
France	56.3	561	953	940	214
Germany	77.5	429	488	1416	±300
Italy	57.8	373	772	826	177
Japan	124.5	350	370	2830	207
Netherlands	14.9	162	196	232	38.9
Spain	39.8	161	194	336	53.8
Sweden	8.4	84	92	170	10.7
Switzerland	6.7	55	±100	188	29.5
UK	57.3	481	1200	646	179
USA	252.5	2069	4200	4961	812
Total	759.5	5264	± 9250	13575	±2100

items that were requested. Not all countries have given such a breakdown; it lacks for Belgium, Germany and the USA. There is reasonable agreement for eleven of the remaining ones, but Finland is very much deviating. For the eleven the distribution is 34 ± 10% for salaries, 16 ± 11% for basic support and 50 ± 10% for installations (17 ± 7% for ground-based and 34 ± 18% for space facilities). Finland has 76% for basic support, so there is some indication here that for that country more indirect costs have been included and the budget quoted may be much too high. We should keep this in mind.

For personnel the figures include permanently employed research staff, postdocs and personnel paid on grants, and technical and administrative staff. The latter has been excluded from the number of researchers in the table. These are probably also accurate –at least on a relative scale– to 10 to 15%.

OECD countries not present at the astronomy expert meeting were Austria, Greece, Iceland, Ireland, Luxemburg, New Zealand and Portugal. Although astronomy and astrophysics is practiced in these countries (except Luxemburg), their astronomical communities are much lower fractions of the population and their budgets probably also low fractions of the GNP. Furthermore, these countries produce only very small fractions of the total number of publications in astronomy, such that for most of them I have no publication and citation data. From the countries listed in the OECD report I have furthermore left out Turkey and Norway, since both seem to belong to the same category of countries in terms of the fraction of researchers in the population or the annual budget compared to the GNP. Turkish astronomers in particular may be publishing a significant fraction of their papers in journals not represented adequately in the database used.

The fifteen countries that remain are indeed the major players in the field of astronomy and astrophysics worldwide. The (former) USSR, India, China, Israel, South-Africa, (former) Czechoslowakia, Poland, Mexico, Chile, Brazil and Argentina play non-negligible roles in that these each produce more than 0.25% of all publications in astronomy. The fifteen OECD countries are –as we will see below – responsible for 81% of all astronomical publications in the database and recieve 93% of all citations, at least as far as the journals included by the Institute for Scientific Information are concerned. It should be pointed out that many publications in eastern European countries, such as in the former Soviet Union, that are generally not translated in English, may not enter the data base. The same holds for national periodicals in some other countries.

It should be noted that funding includes essentially all types, namely personnel costs for research as well as technical and administrative staff, operating and investment costs for facilities and contributions to international organisations and it further refers to both astronomy from the ground and from space as well as theoretical astronomy.

The number of IAU-members is not a very good measure of the number of researchers. The ratio researchers to IAU-members comes out as 1.6 $\pm$ 0.6, but the range is from 1.0 (Canada) to 3.0 (Finland). Of the countries considered, the Netherlands has the highest number of IAU-members per head of the population (10.9 per million), but in the number of astronomy researchers per head of the population (13.2 per million) it ranks only 8/9. Vatican City and Ireland have even higher numbers of IAU members compared to the population if we consider all IAU adhering countries.

For most countries the number of researchers has been split into permanent staff and postdocs+graduates (the division was not given for the USA). The fraction of temporary staff (postdocs and graduate students) was 0.31 $\pm$0.17. The Netherlands has the highest fraction (0.58), but is closely followed by Sweden (0.51) and the UK (0.50). The lowest fraction obtains for Japan (0.05) followed by Canada (0.20), Germany (0.22) and France (0.23). Leaving out Japan, the average becomes 0.37 $\pm$ 0.14. The Netherlands seems to rely most on temporary staff, but we know that these are mostly graduate students and postdocs recruited from other countries. The graduate students are usually very successful in securing postdoc positions abroad and a sizable number even tenured positions in other countries. It is generally believed that this somewhat high fraction plays an important role in the vitality of astronomy in the Netherlands. It should be remembered that the number of researchers and that of IAU members is not necessarily compatible, so that one should not conclude that Australia has only 7 graduate students and postdocs.

Also the ratio of researchers to technical and administrative staff varies wildly (these data are also not complete and may not have been determined consistently). The mean is 2.8, but the range is all the way from 0.7 (France, Italy and Switzerland) to 8.7 (Finland). This seems to confirm that more services have taken as basic support by Finland than by the other countries.

The values in table 1 have been used to determine various measures on the level of funding in astronomy.

- *Number of researchers as a fraction of the total population.*
- *Budget per head of the population.*
- *Budget available per researcher.*
- *Astronomy budget as fraction of the GNP.*

Table 2: Rankings in astronomy funding.

Country	Researchers/ Population	Budget/ Population	Budget/ Researcher	Budget/ GNP	Rank
Australia	11	9	8/9	6	9
Belgium	8/9	10	11/12	11	10/11
Canada	12	15	15	15	15
Denmark	6	11	13	12	12/13
Finland	2	1	3	1	1
France	3	4	6/7	3	2
Germany	13	3	1/2	4/5	4
Italy	7	6	6/7	4/5	6
Japan	15	12	1/2	13/14	12/13
Netherlands	8/9	8	8/9	7	8
Spain	14	13	5	8/9/10	10/11
Sweden	10	14	14	13/14	14
Switzerland	5	2	4	8/9/10	3
UK	1	7	11/12	2	5
USA	4	5	10	8/9/10	7
	(10^{-6})	($)	(M$)	(10^{-3})	
Low	3.0	0.8	0.10	0.04	
Quartile	8.0	1.8	0.19	0.11	
Median	13.2	2.5	0.20	0.16	
Quartile	15.0	3.2	0.28	0.21	
High	20.9	5.7	0.56	0.29	

For all these measures the ranks of the countries were determined in the sense that a high rank (here and in what follows this means a *small* number) corresponds to a relatively large commitment to astronomy. These ranks were then added and a final ranking was determined from that. This is given in the upper part of table 2.

Remarkable is the high rank of Finland. The reason for this must be that Finland has probably included too much in the determination of the budget for basic support (see above). Also some countries spend larger fractions of their total budgets on space than others. Outstanding in this respect are Japan (65% and 21% on ground-based facilities, which must be the reason for the high rank for budget per researcher compared to the other rankings in table 2) and Spain (49% of its total budget on space and only 2% on ground-based, giving rise to a similar effect). Sweden commits of all countries the largest fraction of its astronomy budget on ground-based facilities (32%) and relatively less on space (28%). This would correspond to a choice for relatively cheap science. This accords with the general policy that small countries realize that they cannot compete with larger ones across the board and make therefore sometimes quite definite choices. Outstanding also are Canada and Australia. The latter spends a normal fraction of the total budget on ground-based facilities (19%), but essentially nothing on space. Canada, according to the Megascience report, spends only 11% on space facilities, compared to about 34%

Table 3: Astronomical journals.

Journal	Papers	Papers (%)	Citations per Paper	Citations (%)	Outstanding Cit. Rate
Ann. Rev. A & A	76	0.3	19.6	6.5	44.6
Ap. J. Suppl.	362	1.6	9.2	3.2	26.4
Ap. J.	6168	27.0	8.1	48.3	19.0
M.N.R.A.S.	2202	9.7	5.0	10.6	11.9
Astron. J.	1101	4.8	4.7	5.0	12.1
Icarus	765	3.4	4.2	3.1	9.4
Astron. Astrophys.	3785	16.6	3.8	13.5	9.6
Space Sci. Rev.	362	1.6	3.7	1.3	12.1
Solar Physics	936	4.1	3.2	2.8	8.7
Others	7048	31.0	< 3	15.4	< 8.4
Total	22805		4.5		13.1

for the other countries. Indeed Canada has come in with the lowest rank, largely due to the fact that it spends only 30% of its budget on facilities, compared to 50% for the other countries. The decision by Canada to fund 15% of the twin of 8-meter telescopes GEMINI may constitute a major departure from this policy, but it remains enjoying a relatively cheap entry into major USA observing facilities such as the Very Large Array on the ground and many in space.

Some other interesting numbers can be taken from these data. In these OECD countries one out of every 75,000 persons is an astronomical researcher, but for individual countries this ranges from one per 330,000 (Japan) to one per 50,000 (UK). Also note that each person spends every year through taxes about 2.5$ on astronomy and astrophysics, ranging from 0.8$ for Canada to 4.4$ for Switzerland. The average budget per researcher is 200,000$ per year, ranging from 100,000$ for Canada to 560,000$ for Germany and Japan. The astronomy budget is on average 0.016% of the GNP with a range from 0.004% for Canada to 0.028% for the UK.

3 Astronomical journals.

Publication and citation data come from the paper *Scientometric datafiles: a comprehensive set of indicators on 2649 journals and 96 countries in all major science fields and subfields 1981–1985* by Schubert, Glänzel and Braun (1989).

The listings in that paper concern journals that were covered in the Science Citation Index for the full 5-year period. The publication types are articles, reviews, notes and letters (but not non-invited contributions to Conference proceedings), which (as the authors state) are *"the only types that deserve the name citable item and no other publication type is relevant in impact oriented evaluations."* The paper uses the *first author count* for the country assignments, which apparently approximates any reasonable fractional count (dividing up according to countries of co-authors) to 10% for samples of 100 papers and 1% for samples of 1000 papers. The tables employ 108 subfields (of which astronomy and astrophysics is one) among 5 major fields (Life Sciences, Physical Sciences, Chemistry, Engineering and Mathematics). Social sciences and economic sciences were not included in the study. Life sciences include biology and medical science; physical sciences physics, astronomy and geosciences. The year of the paper is that of the date on the cover of the journal issue. The citation period is the same 5 years as the publication years, which means that the actual citation period is between 0 and 5 years and that about half of the papers reach their citation peak (which they quote as 2–3 years after publication) in this period. However, in astronomy this period may be rather longer (see the studies by Abt, referred to below). Also the citation histories of those papers on which I myself was a (co-)author show rather consistently a peak at 4 to 5 years after publication.

In the first place it is of interest to look at the citation rates of the journals. The data are compared in table 3. *Science* and *Nature* have not been included, because no data for astronomy papers separately in these journals were avaialble. The citation rate (citations per paper) gives the average number of citations that a paper in that journal has received in the period indicated. The journals have been given in order of this parameter. There also is a second parameter that the authors call the *outstanding citation rate* in an attempt to correct for the effect that certainly *"in the particular case of choice of source and citation periods, a considerable part of the publications has no real chance at all of being cited, while others may reach through their citation peak"* and that the distribution of citations is very skew. Therefore the outstanding citation rate is calculated as the average of those citation rates that are higher than the average.

First concentrate on the major general journals which have little emphasis on particular fields of astronomy and astrophysics. Those American journals (Ap. J. and Astron. J.) are responsible for about 33% of all papers and they receive about 56% of all citations. For the European journals (A & A and MNRAS) this is respectively 26% and 24%. The citation rates for US journals is 7.3 compared to 4.4 for the European ones. The US journals have a page charge; the European ones don't. MNRAS finances itself by larger subscription rates (especially for libraries) and A & A recieves funds from the participating nations and levies no page charge for researchers from these countries. European astronomers are therefore mostly dependent on these journals.

It appears that one has a higher chance of being cited in the US journals. There may of course be an effect of US astronomers citing preferentially from their own community. As a test of this we may look at the citation rates of Australian papers (Australian astronomers publish three-quarters of their papers in the 4 major US and European journals). Their citations rate in US journals is 8.1 and in European journals 4.9, close to the total citations rates for these journals. To investigate this further I divided the countries in three blocks, namely Western European, North American and the rest of the world. For these groups the citation rates in the European journals are respectively 4.3, 4.5 and 3.4; for the American journals these are 6.8, 7.8 and 5.8. So we see that the area of origin of the paper has little effect on the citation rate within a journal and this confirms that the main cause of the differing citation rates is the fact that American –but also non-American– astronomers refer most often to publications in American journals. Not unjustifiably, most astronomers consider the Astrophysical Journal as the primary general journal in the field of astronomy and astrophysics, but this does put non-American astronomers that cannot afford the page charge at a disadvantage.

As an example, the Netherlands publications in the period have the following distribution over the journals: A & A 324 (62%), Ap. J. 63 (12%), MNRAS 47 (9%) and less than 10 in other journals each. The citation rates for Netherlands papers in these journals are respectively 5.6, 12.3 and 5.1. Note that the citation rate of Netherlands papers in Ap. J. is higher than the average for that journal. From this and the above analysis one may expect that the Netherlands may gain a factor of up to 2 in citations, if funds were available to publish most papers in Ap. J. This holds of course also for other European countries.

Important to note is that the USA has published 7% of the A & A papers, but with a citation rate of 3.7 (compared to 8.4 for American papers in Ap. J.) and the UK 4% of the papers at a citation rate of 1.8 (5.2 for UK papers in MNRAS). For comparison, American papers get a citation rate of 6.1 in MNRAS (higher than the average for that journal), but UK papers in Ap. J. recieve 7.2 citations (below the journal's average).

H. Abt has produced a number of studies related to publishing and citation characteristics of astronomical papers. He has recently summarized this (Abt, 1990, where a complete list of references is given). In one of these studies he tested the widely held view of a preferences of American authors to cite American papers by looking at the frequency of references to the same journal in which a paper is published. Such a trend is indeed clearly noticable, but holds as well for European journals. Abt concludes that this "self-citation" is a global feature. However, because of the dominance in publications by the US and the high citation rates in American journals, it does put European and other countries at a disadvantage in an absolute sense (in the total number of citations) and in that manner it does enhance the US inpact on astronomy. Rejection rates between the US and European journals are not noticably different (Abt quotes 10% for Ap. J. and other US journals and similar numbers of 10 – 15% are usually quoted for European ones).

4 Output of astronomical research.

From the tables in Schubert *et al.* some relevant information can be taken for the same set of countries as before (table 4). I have combined the data for former West- and East-Germany. The total number of publications world-wide is 22805 and the average citation rate 4.53 per paper (see table 3). The 'total' citation rate at the bottom of table 4 is a weighted average determined from that line in the table. From these data and keeping in mind that the average paper has a citation period of only 2.5 years, it also follows that on average a paper published by astronomers in these countries recieves about 10 citations in the first five years. For US papers this is somewhat higher (the USA dominates the total number of publications), but it can be as low as a few for Spanish papers, at least in the first half of the eighties.

Remarkable countries not in the OECD lists are the (former) USSR (8.11% of the publications and mean citation rate of 0.97), India (3.80% and 0.85) and (former) Czechoslowakia (1.06% and 1.05). Of further interest is Chile (0.78% and 7.46!). The citation rate is the highest worldwide (even ahead of the USA), but this surely is due to the two American observatories and ESO in that country. Switzerland also is also very high and one may argue that this is due to CERN. My judgement would be that this is probably not a direct effect, as few CERN scientists are publishing in astronomical journals. Similarly, I judge the effect of ESTEC of little impact on the Netherlands figures as the large majority of

Table 4: Publication and citation data in astronomy 1981-1985.

Country	Publications	World Percentage	Citations	World Percentage	Citation Rate
Australia	443	1.94	2316	2.24	5.23
Belgium	216	0.95	634	0.61	2.94
Canada	903	3.96	3393	3.28	3.76
Denmark	91	0.40	363	0.35	4.01
Finland	76	0.33	196	0.19	2.38
France	1070	4.69	3873	3.75	3.62
Germany	2108	9.19	7586	7.34	3.60
Italy	879	3.86	2743	2.66	3.12
Japan	628	2.75	1773	1.72	2.82
Netherlands	542	2.38	3338	3.23	6.16
Spain	123	0.54	187	0.18	1.32
Sweden	142	0.62	536	0.54	3.92
Switzerland	186	0.82	1238	1.20	6.66
UK	2058	9.03	8744	8.47	4.25
USA	8786	38.54	59288	57.40	6.75
Total	18251	81.42	96416	93.16	5.28

publications used here are astronomical and little astronomical research is done at ESTEC itself. Similarly I assume that the location of the Villafranca European (ESA) operations center of the International Ultraviolet Explorer (IUE) satellite has no important effect on the conclusions concerning Spain. On the other hand, the location of the European Southern Observatory (ESO) headquarters in Germany is likely to have an effect on the numbers for Germany.

There are six measures for the quantity, quality and impact of the output of astronomical research that I have used as an indication of the performance. The first three are:

- *Citation rate.*
- *Citations per researcher.*
- *Publications per researcher*

The other three are ones that have been given in the Schubert *et al.* paper. These are:

- *Relative citation rate.* First an expected citation rate is calculated for each country which is based on the number of publications and the citation rates for the journals in which these papers have appeared. The relative citation rate then is the ratio between the observed and expected citation rates.
- *Activity index.* For each country this is the ratio of the world share it has in the number of publications in astronomy and that share for all sciences.

Table 5: Astronomy publication and citation rankings.

Country	Cit. Rate	Cit./ Res.	Publ./ Res.	Rel. Cit. Rate	Act. Index	Attract. Index	Rank
Australia	4	6	4	4/5	9	5	4
Belgium	12	10/11	9	10/11	4	9	9/10
Canada	8	2	2	14	8	8	7
Denmark	6	9	11	7	13	12	11
Finland	14	14	14	10/11	12	13	14
France	9	12	12/13	9	6/7	6	9/10
Germany	10	3	1	8	3	3	3
Italy	11	13	12/13	12/13	1	2	8
Japan	13	10/11	7/8	12/13	14	14	13
Netherlands	3	1	3	2	2	1	1
Spain	15	15	15	15	11	11	15
Sweden	7	8	10	4/5	15	15	12
Switzerland	2	5	6	1	10	10	5
UK	5	7	7/8	7	6/7	7	6
USA	1	4	5	3	5	4	2
Low	1.32	1.0	0.6	0.41	0.38	0.25	
Quartile	2.94	4.1	1.1	0.81	0.55	0.38	
Median	3.76	5.9	1.7	0.93	0.94	0.83	
Quartile	5.23	14.1	2.2	1.01	1.11	1.23	
High	6.75	17.0	4.3	1.77	1.69	1.68	

- *Attractivity index.* For each country this is the ratio of the world share it has in the number of citations and that share for all sciences.

The same procedure using rankings has then been used, where a high rating (low number) means a good performance. The result is in table 5.

The Netherlands has come out at the top of the list and is indeed high in all six measures. To my surprise the UK is lower on the list than I would have expected and Germany is higher than expected. The latter may very well be partly an effect of the location of ESO headquarters, but I have no good explanation for the performance of the UK. The others correspond in their ranking to within 1.5 ranks on average to what I had predicted intuitively before doing this excercise. It would certainly be very interesting to have the same analysis for the years 1986-1990 and to see what changes have come about. In particular I would guess that Spain is on the rise both in size of the community and in quality of the output of research; many international collaborations have improved the level of astronomy. This is to a large extent the result of the development of the Canary Islands observatories.

Table 6: Ranks for the relation between funding and output.

Country	Budget/ Publ.	Budget/ Cit.	Funding-Output	Rank
Australia	4	4	3/4	3
Belgium	6	8	7/8	8
Canada	1	1	1	1
Denmark	8	7	6	6/7
Finland	14	14	15	14/15
France	11/12	11	14	13
Germany	9	10	7/8	9
Italy	11/12	12	11/12	11/12
Japan	13	13	9	11/12
Netherlands	2	2	2	2
Spain	15	15	13	14/15
Sweden	7	9	5	6/7
Switzerland	10	6	11/12	10
UK	3	5	10	5
USA	5	7	3/4	4
	(k$)	(k$)	(ranks)	
Low	23	6	-8	
Quartile	92	20	-3	
Median	101	32	0	
Quartile	201	65	2	
High	437	288	13	

5 Comparison of astronomy funding with output.

We can now make a comparison of the level of funding and the output. I have used three measures that can be derived from the information in the previous sections:

- *Budget per publication.*
- *Budget per citation.*
- *Difference in rank between output and funding.*

The results of this can be found in table 6. The entry 'ranks' in the bottom part of the table refers to the difference in rank between tables 2 and 5.

Again the Netherlands comes in very high. The first place of Canada is to a large extent due to the fact that only a small fraction of the budget is for facilities and within that for space and that the science is therefore relatively cheap. The position of Finland is affected by the probably inconsistent input data for funding.

In this comparison it should be kept in mind that the funding refers to recent years and the output to the first half of the eighties. This will often not be a large effect (budgets, number of researchers and the population will not have changed much, at least

Table 7: Publication and citation data for all sciences 1981-1985.

Country	Publica-tions	World Perc.	Cita-tions	World Perc.	Citation Rate	Resear-chers
Australia	42775	2.23	120697	2.03	2.82	22588
Belgium	16395	0.85	50523	0.85	3.08	6430
Canada	80081	4.17	235231	3.95	2.94	29177
Denmark	15790	0.82	54844	0.92	3.47	4930
Finland	12066	0.63	32748	0.55	2.71	$\pm$4200
France	89531	4.67	250460	4.20	2.86	55360
Germany	129357	6.74	369318	6.20	2.86	48976
Italy	43706	2.28	101070	1.70	2.31	38586
Japan	134187	6.99	343723	5.77	2.56	124814
Netherlands	32657	1.70	114737	1.93	3.51	1284
Spain	15680	0.82	25828	0.43	1.65	11398
Sweden	31543	1.64	115854	1.94	3.66	8048
Switzerland	23454	1.22	106958	1.70	4.56	6044
UK	171858	8.96	572995	9.61	3.33	38566
USA	706114	36.81	3029147	50.82	4.29	193667
Total	1555194	80.53	55228133	92.60	3.55	605600

in a relative sense), but it will be an effect for Spain that would probably have ended higher if the publication and citation data would have referred to more recent years. Note that on average a budget of about 100,000$ is required per publication.

6 All sciences.

The publication and citation data for all sciences combined for the same set of countries as before from the Schubert *et al.* study are collected in table 7. The data are similar to those for astronomy and astrophysics exclusively in table 4 and I recall that social and economic sciences are not included in the total science numbers. The number of researchers divided by the population is $(0.84 \pm 0.25) \times 10^{-3}$. For Finland I could not find the number of researchers and it has been estimated assuming this average ratio. The fraction of researchers that are astronomers is 1.5 $\pm$ 0.7% or one out of every 65.

The USSR has 7.27% of all publications and a mean citation rate of 0.70 and for India these are 2.64% and 0.96. Also Israel is fairly high (1.06% and 2.69).

I have taken the same first four measures for the performance:

- *Citation rate.*
- *Citations per researcher.*
- *Publications per researcher.*
- *Relative citation rate.*

Table 8: Output rankings for all sciences.

Country	Cit. Rate	Cit./ Res.	Publ./ Res.	Rel. Cit. Rate	Publ./ Pop.	Cit./ Pop.	Rank
Australia	11	11	11	12/13	7	8	11
Belgium	7	8	9	8	10	10	8
Canada	8	7	7	12/13	4/5	6	7
Denmark	5	5	5	3	3	4	4
Finland	12	9	6	11	8	9	10
France	9/10	12	12	10	12	12	12
Germany	9/10	10	8	3	11	11	9
Italy	14	14	14	14	14	14	14
Japan	13	13	15	9	13	13	13
Netherlands	4	6	10	5	9	7	6
Spain	15	15	13	15	15	15	15
Sweden	3	4	2	2	1	2	2
Switzerland	1	1	3	1	2	1	1
UK	6	3	1	6/7	4/5	5	5
USA	2	2	4	6/7	6	3	3
					(10^{-3})	(10^{-3})	
Low	1.65	2.3	1.1	0.64	0.4	0.6	
Quartile	2.77	5.3	1.9	0.96	1.7	4.8	
Median	2.90	7.8	2.7	1.00	2.4	6.9	
Quartile	3.47	11.1	3.2	1.06	3.0	10.0	
High	4.56	17.7	4.5	1.22	3.8	16.0	

Now activity and attractivity indices can of course not be formed and I have replaced these by

- *Publications per head of the population.*
- *Citations per head of the population.*

The resulting rankings are given in table 8. Interesting are the low positions of major European countries as France and Italy (and also Japan) and the high positions of small countries as Switzerland, Sweden, Denmark and the Netherlands. Is it easier for a small country to excell, but more difficult for a large one because inevitably it will have a sizable community of average performance?

7 Comparison astronomy to other sciences.

The relative success of astronomy compared to all sciences can be measured from:

- *Difference in ranking of output for all sciences and for astronomy.*

Table 9: Ranks of relative performance of astronomy to all sciences.

Country	Output All-Astron.	Rel. Cit. Rate Astron./All	% of Cit. Astron./All	Rank
Australia	1/2	3	5	2
Belgium	10/11	11/12	9	10
Canada	7/8/9	14	8	9
Denmark	14	11/12	12	14
Finland	12	10	13	12/13
France	5	8	6/7	6
Germany	3/4	7	3	4
Italy	1/2	5/6	2	3
Japan	7/8/9	13	14	12/13
Netherlands	3/4	2	1	1
Spain	7/8/9	15	11	11
Sweden	15	9	15	15
Switzerland	13	1	10	8
UK	10/11	4	6/7	7
USA	6	5/6	4	5
	(ranks)			
Low	-10	0.64	0.28	
Quartile	-3	0.85	0.38	
Median	0	0.95	0.83	
Quartile	3	1.00	1.10	
High	6	1.45	1.67	

- *Ratio of the relative citation rates in astronomy and in all sciences.*
- *Ratio of the world percentage of citations in astronomy and in all sciences.*

The resulting ranks are given in table 9.

This comes out again more or less as I would have expected, except that Spain is likely to have increased its position in more recent years. It would have been interesting to compare the share of astronomy funding in the total budget for civilian R & D. However, these data are not complete in the OECD report. For the 7 countries that have given this number it ranges between 1 and 3%. It is also probable that these numbers have not been calculated in a consistent manner.

8 Conclusion.

By way of conclusion I collect in a single table (table 10) the resulting final rankings of the preceeding sections. I stress that the position of Finland is probably affected seriously by the inclusion of many indirect costs for basic support that were not taken along by the other countries.

Table 10: Summary of various rankings of OECD countries.

	Astronomy Funding	Astronomy Output	Astronomy Budget-Output	All Science Output	Astronomy-All Science
1	Finland	Netherlands	Canada	Switzerland	Netherlands
2	France	USA	Netherlands	Sweden	Australia
3	Switzerland	Germany	Australia	USA	Italy
4	Germany	Australia	USA	Denmark	Germany
5	UK	Switzerland	UK	UK	USA
6	Italy	UK	Denmark	Netherlands	France
7	USA	Canada	Sweden	Canada	UK
8	Netherlands	Italy	Belgium	Belgium	Switzerland
9	Australia	France	Germany	Germany	Canada
10	Belgium	Belgium	Switzerland	Finland	Belgium
11	Spain	Denmark	Japan	Australia	Spain
12	Denmark	Sweden	Italy	France	Japan
13	Japan	Japan	France	Japan	Finland
14	Sweden	Finland	Spain	Italy	Denmark
15	Canada	Spain	Finland	Spain	Sweden

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10 References

Abt, H.A. 1990, *Current Contents 39 and 40* and reference therein; in particular *P.A.S.P.* **93**, 207 (1981), **99**, 1329 (1987), **101**, 555 (1989).

OECD (1993), *ASTRONOMY*, Report of the Megascience Forum of the Organisation for Economic Co-operation and Development (Paris).

Schubert, A., Glänzel, W., Braun, T. (1989), *Scientometrics* **16**, 3.