Der Wissenschaftsfonds.

A contest between nations; or how far is Austrian research behind that of the world leaders?

An analysis on the competivness of Austria's scientific research in the natural and social sciences

Vienna, October 2007

A funding organization such as the FWF is interested not only in awarding funding (input) for project applications based on criteria of high quality but also in ensuring that the results of the projects it supports are of high quality. In basic research, by far the most important criteria for measuring output are the number publications in highly ranked, international scientific organs and how these are appreciated (i.e. cited) by the scientific community.

In natural and social sciences, publications and their citations from more than 8000 scientific journals can be quantitatively analysed by means of data from the ISI "Web of Knowledge". However, bibliometric procedures are still contentious. Comparison between persons, between institutions and between research disciplines are problematic, as publication and citation cultures may vary dramatically even within a scientific field (see also May 1997: 796). Nevertheless, analysis large amounts of data gathered over long periods reveals some interesting trends: statistical bias generally levels out with larger data sets.

These considerations led the FWF to analyse Austria's international position in basic research. Data were taken from the past ten years. The precise aim of the study was to determine how the results of research in Austria (= publications) are internationally received (= citations). How good is the research that was enabled by FWF support? Austrian research politics have set the ambitious goal of "world class" research and it is thus interesting to consider how large is the gap between Austria and the leading nations.

Comparisons between countries are not new. Two prominent examples are the studies of Robert M. May (1997): "Scientific Wealth of Nations", *Science* 275, 793 ff. and David A. King (2004): "The Scientific Impact of Nations", *Nature* 430. Austria did not have a leading position, either in May's study (using ISI data from 1981-1994) or in that of King (based on ISI data from 1993-2002). Instead, it became clear that in comparison with its wealth Austria's performance in terms of scientific citations is moderate.

Fig. 1: Correlation between intensities of citations and wealth (King 2004)

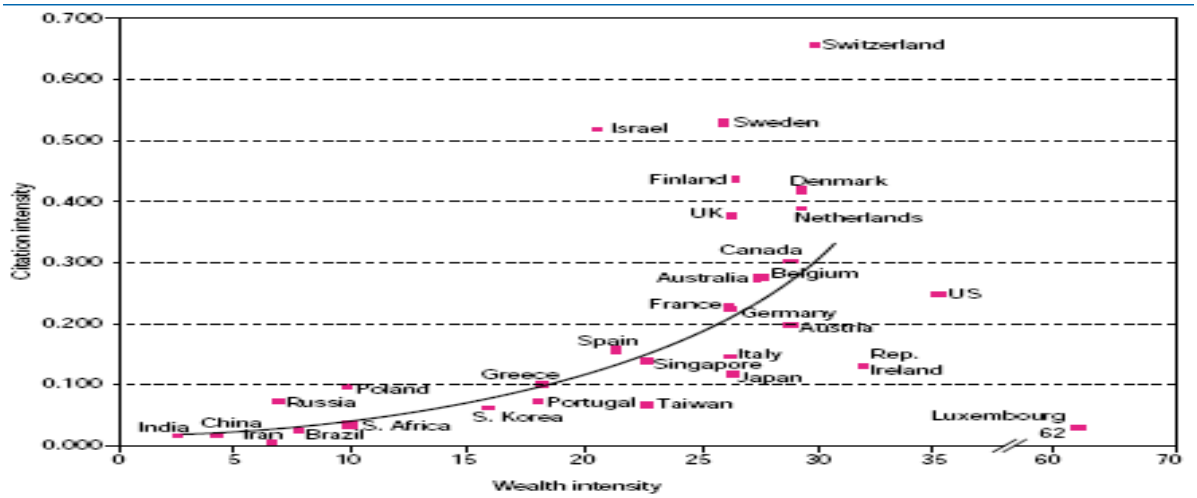


Figure 2 Comparing economic and scientific wealth. National science citation intensity, measured as the ratio of the citations to all papers to the national GDP, shown as a function of the national wealth intensity, or GDP per person, for the 31 nations in the comparator group. GDP and wealth intensity are given in thousands of US dollars at 1995 purchasing-power parity. Sources: Thomson ISI, OECD and the World Bank.

Which are the leading nations?

The FWF makes no claims that the methods used to prepare the present report reach the levels of sophistication of those employed in May's and King's elaborate studies. The present work focusses on Austria's position in comparison to the top nations based on current data (ISI data 1997-2006), on determining appropriate weightings and on the results for individual disciplines.

It is no surprise that the large countries such as the USA, Great Britain, Germany, Japan and France lead the field in terms of absolute numbers of publications and citations (Austria lies in 22nd place). However, a ranking based on absolute numbers does not take the different features of the various nations into account.

For a relatively small and prosperous country such as Austria, it is reasonable to make comparisons with countries that have similar structural features, primarily countries with comparable populations and economic performances. Although population figures are freely available, there are only indirect figures for economic and scientific performance. A further limitation is that long-term data relating to expenditure on basic research and on R&D are either not available or incomplete.

- As a first approximation, the citations from a country were related to its population and its GDP (source: OECD data). Comparison of the figures obtained for the two weighting factors enables a reciprocal check.
- In a subsequent step, a "world class" level was defined as the average number of citations per capita and per unit of GDP for the top five countries in each scientific discipline.
- Finally, a "gap factor" from the target value "world class" was calculated to see how far Austria lags behind the average of the top five nations. Put differently: the "gap factor" expresses how much more the Austrian publications in ISI must be cited, assuming other figures remain the same, to break through into the top five nations.

Tab. 1: Austrian citations and those of the top five nations per capita and per unit of GDP; Austria's "gap factor" to the average of the top five nations (1997-2006)

Discipline	Citations per capita		Citations per unit of GDP	
	Top 5	"gap"	Top 5	"gap"
All disciplines	SUI-SWE-DEN-FIN-NED	2.1	SUI-SWE-DEN-FIN-ISR	2.2
Agriculture	NZL-DEN-IRL-ICE-FIN	5.8	NZL-DEN-IRL-FIN-ICE	6.3
Biology & biochemistry	SUI-SWE-DEN-ISR-UK	2.6	SUI-SWE-DEN-ISR-UK	2.7
Chemistry	SUI-SWE-DEN-ISR-NED	2.2	SUI-SWE-ISR-DEN-NED	2.2
Clinical medicine	SUI-SWE-FIN-DEN-ICE	2.0	SWE-FIN-SUI-DEN-ICE	2.0
Computer science	ISR-SUI-SIN-SWE-DEN	2.8	ISR-SIN-SUI-SWE-DEN	3.1
Economics & business	USA-UK-ISR-NED-SWE	4.0	ISR-UK-SWE-NED-NZL	4.0
Engineering	SIN-SUI-SWE-ISR-DEN	2.7	SIN-SUI-ISR-SWE-SLO	2.8
Environment & ecology	SWE-DEN-NZL-FIN-NOR	4.6	NZL-SWE-FIN-DEN-EST	5.2
Geosciences	ICE-SUI-NOR-NZL-AUS	5.0	ICE-SUI-NZL-NOR-AUS	4.9
Immunology	SUI-SWE-NED-DEN-ICE	2.3	SUI-SWE-NED-ISR-DEN	2.3
Material science	SIN-SUI-SWE-ISR-FIN	2.0	SIN-SWE-SLO-SUI-ISR	2.3
Mathematics	ISR-SUI-FRA-SLO-CAN	1.5	ISR-SLO-NZL-FRA-CH	1.9
Microbiology	SUI-DEN-NED-SWE-BEL	2.4	SUI-DEN-SWE-NED-UK	2.4

Molecular biology & genetics	SUI-ICE-ISR-UK-SWE	2.2	SUI-ICE-ISR-UK-SWE	2.3
Neuroscience & behaviour	SUI-SWE-CAN-ISR-FIN	2.2	SUI-SWE-ISR-FIN-CAN	2.3
Pharmacology & toxicology	SUI-SWE-NZL-ICE-UK	2.7	NZL-SUI-SWE-ICE-UK	2.8
Physics	SUI-ISR-DEN-SWE-FIN	1.8	SUI-ISR-DEN-SWE-SLO	1.9
Plant & animal science	NZL-DEN-ICE-NOR-SUI	3.1	NZL-DEN-ICE-SWE-AUS	3.3
Psychiatry & psychology	CAN-NED-NZL-UK-ISR	4.4	NZL-ISR-UK-CAN-NED	5.0
Social sciences	UK-USA-ICE-AUS-NZL	7.5	UK-NZL-AUS-SWE-ICE	7.9
Space science	NED-SUI-UK-DEN-AUS	4.0	NED-UK-DEN-SUI-ISR	4.0

The results of weighting by population and by GDP are broadly similar. Austria's distance from the top is slightly greater when the latter factor is used, largely because countries such as Israel and New Zealand with comparatively low GDPs but highly cited scientific publications are favoured. On the other hand, countries with a high GDP, such as the USA and Austria, lose ground somewhat.

The statistics are prone to artefacts in certain cases. Some of these include:

- Some of Iceland's results, for example in geosciences, are unusually high. Because of the relatively small population, this result could arise from a single, very good research group. If the figure for Iceland is discounted, Austria's "gap" in geosciences is only marginally reduced.
- Similarly to Iceland in geosciences, Switzerland dominates the scene in physics, very probably as a result of CERN. In other words, high-ranking international or privately financed research institutes can significantly increase a country's citation value. Of course, such institutes are generally established and flourish in countries where the surrounding research is of an appropriate standard.
- In economics and social sciences it is sometimes argued that publications in local languages are important or that the dominance of the English-speaking countries is a historical accident. If this argument is taken into account by including in the analysis only countries where English is not the native language, the "gap factor" in economics is reduced from 4.0 to 3.4 (from 4.2. to 3.7) and in social sciences from 7.5 to 6.2 (from 7.9 to 6.2).

Even taking into account these artefacts, which have little effect on the overall conclusions, Austria's position has not improved significantly in comparison with the results of May and King. In general, basic research in Austria still occupies a mid-table position. Only mathematics and physics have closed the gap on the word leaders. On the other hand, economics and social sciences, agriculture and environmental sciences and space science have fallen further down the table.

For humanities, it is currently possible to undertake a similarly well grounded analysis only to a very limited extent. Small-scale citation analyses based on ISI's *Arts and Humanities Citation Index* (AHCI) and on SCOPUS indicate that also in these disciplines the Scandinavian countries, Holland and Israel are among the top countries and that Austria's "gap" to the top nations is not inconsiderable.

Where should projects funded by the FWF be ranked?

For a considerable period of time, physics and mathematics (as well as some disciplines in the humanities) have enjoyed by far the highest success rates in applications for funding to the FWF (generally above 50%), whereas the opposite is true for economics and social sciences as well as for agriculture and space science (generally below 30%). These figures provide an initial indication for the accuracy of the FWF's funding decisions.

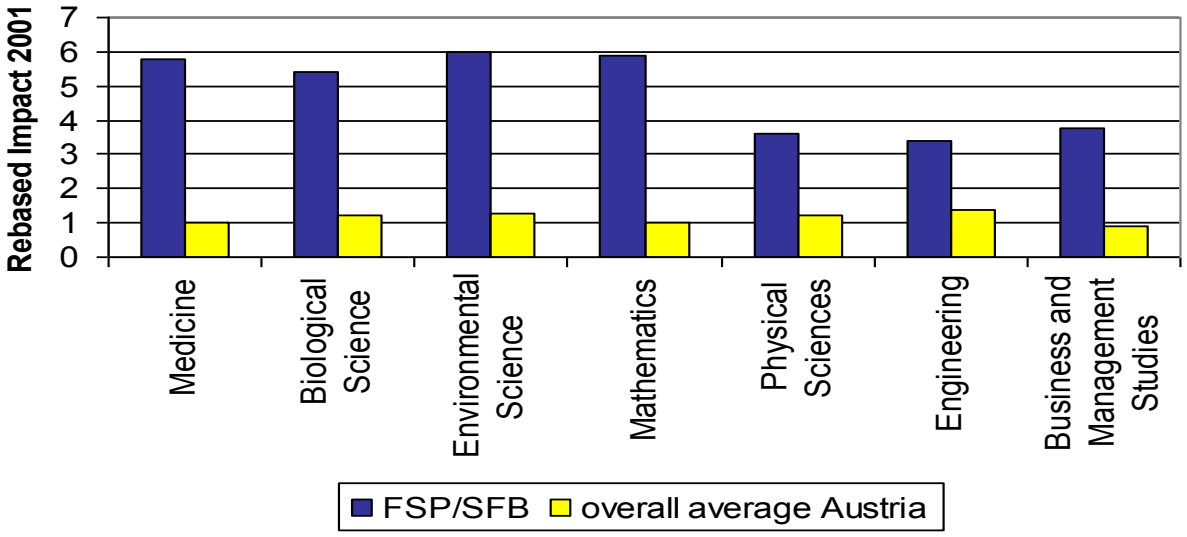
More systematic evidence comes from bibliometric studies undertaken by external experts in the course of evaluations of FWF programmes.

At the start of 2003 the FWF began to perform *ex post* evaluations of its stand-alone projects. Among other indicators, data were gathered relating to publications resulting from projects funded by the FWF. In 2006, the data were used by Evidence Ltd as the basis for a citation analysis by means of ISI. Because of the limited amount of data (N=4457), a breakdown by subject area was not possible. However, the analysis of all disciplines together showed that publications resulting from FWF projects are cited significantly more often (by a factor of ca. 1.5) than the average scientific publication from Austria. The citation rate of publications from FWF-funded projects was even slightly higher than the average from top nations such as Switzerland, Holland, Sweden or Finland.

Citation analyses of the FWF's priority research programmes (SFB, NFN) proved even more conclusive because comparisons between different disciplines was possible. The FWF's priority research programmes really do represent its programmes of excellence and thus the discrepancy between its publications and the "Austrian average" could be expected to be greater. Indeed, publications from the FWF's priority research programmes in all scientific areas funded do have significantly higher citation values than the average figure for publications from Austria (by a factor of 2.5-2.6). Furthermore, the citation values of scientists within FWF priority research programmes were compared with those of the same people achieved when working outside the priority research programmes. The results showed that the FWF's support for priority research programmes enabled previously first-rate scientists to attain an additional increase in the frequency with which their publications were cited (by a factor of 1.5-2.5). Finally, the study showed that publications resulting from the FWF's priority research programmes were cited considerably more than the average publications from top nations such as Switzerland, Holland, Sweden or Finland.

In conclusion, it is clear that the FWF's research funding activity, founded on a rigourous, international peer-review system, dramatically increases the international impact of the scientists it supports, who as a result are able to work at a level that can be classified as world-leading.

Fig. 2: Citation impact for projects in FWF priority research programmes compared with "Austrian average" 2001



Source: http://www.fwf.ac.at/de/downloads/pdf/networks_evaluation.pdf

What can be learned?

With very few exceptions, all leading scientific nations, in particular smaller ones such as Switzerland, Israel, Sweden, Denmark, Finland or Holland, are world-leading not only overall but also in all individual scientific disciplines. This provides a strong indication for a wide-ranging effort to attain international quality in all areas of science and argues (also for countries with smaller economies) against too strong a focus on particular disciplines. It appears rather to be the case that excellence in individual disciplines or fields of research is hardly possible without excellence in most disciplines.

The jump to a world-leading position in basic research cannot be attained in a matter of a few years. Many of today's top nations have invested in the necessary resources, structures and incentives over a period of decades. And in one aspect the majority of the leading nations differ from Austria: science is accepted as a competitive system directed towards high performance. This is evidenced by the quality-oriented schemes in places for recruiting personnel at research institutes and by the importance of obtaining third-party funding awarded via competitive procedures. This latter point can be illustrated by comparing the budgets of the most important sources of third-party funding for basic research:

Tab. 2: Budgets of funding organizations in the leading nations and in Austria 2006*

Country	Funding organization(s)	Budget in Mio. €	Expenditure per capita (in €)
Switzerland	SNF	296	39,5
Sweden	VR + FAS + FORMAS	387	49,0
Denmark	DNRF + DCIR	215	38,9
Finland	AKA	239	45,8
Holland	NWO	523	31,3
Austria	FWF	151	18,5

* Source: Information from annual reports; for Denmark estimates based on advance notice and on data from 2005

It is clear that almost all leading countries allocate considerably more money for the competitive promotion of basic research than Austria does. However, Austria's "gap" in citation indexes is far larger than the discrepancy in research funding. This point is illustrated by two examples:

- In 2004, Switzerland invested 65% more in R&D (public expenditure for R&D was ca. € 1.9 billion, about the same as in Austria) but in the period from 1997 to 2006 Switzerland achieved almost three times as many citations as Austria.
- From 1997-2006 Israel produced a GDP that was lower by more than 30% than that of Austria but over the same time period it achieved almost 25% more citations.

It is clear that, apart from financial investments, the incentive structures at the research institutions are also – and primarily – important. Robert May has already identified this point as a significant disadvantage of research in continental Europe. "*The nonhierarchical nature of most North American and northern European universities, coupled with the pervasive presence of irreverent young undergraduate and postgraduate students, could be the best environment for productive research."* (1997: 798)

In case of questions please contact
Falk Reckling
Tel.: 01-5056740-8301
Email: Falk.Reckling@fwf.ac.at