

# **The effect of university-industry collaboration on the scientific impact of publications: the Canadian case (1980-2005)**

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## **Abstract**

Previous research on university-industry collaboration in Canada concluded, using mean impact factors as a proxy, that the scientific impact of such research is not inferior to that of university research. Using field-normalized impact factors and citation counts, this paper reexamines the Canadian case. It shows that, when impact factors are field-normalized, university-industry papers are published, on average, in journals with lower impact factors than papers originating from universities only. However, field-normalized citation values reveal the opposite: the average scientific impact of university-industry papers is significantly above that of both university-only papers and industry-only papers. Collaboration with industries is, thus far from detrimental to the scientific impact of university research and even increases it significantly.

## **Introduction**

Collaboration in scientific research is generally regarded as being something positive which must be encouraged (Katz and Martin, 1997). Many efforts are thus made, generally in the form of governmental or institutional policies, to reinforce all kinds of collaborations. Several initiatives also aim at fostering collaboration between various organizations active in research—particularly universities and industries—in order to integrate potential users of research as early as possible into the research process (OECD, 1999). Along the same lines, Gibbons *et al.* (1994) and Leydesdorff and Etzkowitz (1996) suggest that the organization of scientific research is changing and that, in contemporary societies, knowledge is more and more produced in collaboration between universities and industries.

This paper aims at studying, with bibliometric data and methods, the scientific impact of research performed by university researchers working in collaboration with industry. Several bibliometric studies have been published so far on university-industry collaboration. They generally come to the conclusion that these university-industry collaborations are advantageous to the two partners; the most tangible benefit for industry is a faster access to the new discoveries of universities, whereas in return, university researchers have access to equipment, research funds and an external viewpoint on their own works (Lee, 1997). At the individual level, Lee and Bozeman (2005) showed that US researchers who collaborate—all types of collaboration included—are generally more productive in terms of publications than researchers working alone. Although they represent a small percentage of collaborative activities, university-industry collaborations

have a positive effect on productivity. Other researchers, such as Katz and Hicks (1997), obtained similar results for the UK science system. Indeed, UK articles published in collaboration with other institutions (be it universities, industries or government laboratories) received, on average, more citations than articles produced without such collaborations. This was also observed in the particular case of university-industry collaborations.

For the Canadian case, university-industry collaborations did not seem to have any negative impact on the quality of the journals in which these articles were published (Godin and Gingras, 2000). The mean impact factor of journals in which university-industry collaboration were published were similar to that of papers written by university researchers only. This analysis of the Canadian case, however, had several limits. First, it used the impact factor—with its now well known limitations<sup>1</sup>—as a proxy of the expected impact of papers published. Second, impact factor values were not normalized by subfields. Given the fact that the average impact factor of subfields can vary considerably (for example the case of cancer research is quite different from that of physiology), aggregate impact factor values can be distorted by the varying relative presence of institutions or countries in a given set of subfields. This paper thus revisits the Canadian case by using more recent data and more sophisticated indicators such as 1) field normalized impact factors and 2) field normalized citation rates with four-year citation windows.

## **Methods**

### ***Database***

The bibliometric database used in this study was built by the Observatoire des sciences et des technologies (OST) using the CD-ROM version of the Science Citation Index (SCI) of Thomson Scientific. This database indexes the vast majority of the articles published by more than 3 700 scientific journals which are among the most important and recognized in their respective fields. The data compiled covers the years 1980 to 2005. The present analysis is based only on the three types of documents which reflect best the production of new knowledge: articles, reviews and notes. Together, these three categories represent more than 90% of the documents published in journals indexed by the SCI. The field and subfield classification used in this paper was developed by ipIQ for the National Science Foundation. It break downs scientific journals into eight disciplines (biology, chemistry, physics, mathematics, engineering, earth and space sciences, clinical medicine and biomedical research) and about a hundred specialties.

In order to compile the scientific production of universities and industries, a sector—university, industry, government (provincial or federal), hospital or other—was assigned to each Canadian institution present in the database (N≈15,000). An article was considered as the result of a university-industry collaboration when it contained at least one address of a university and at least one from an industry.

### *Normalization of impact factors and citations*

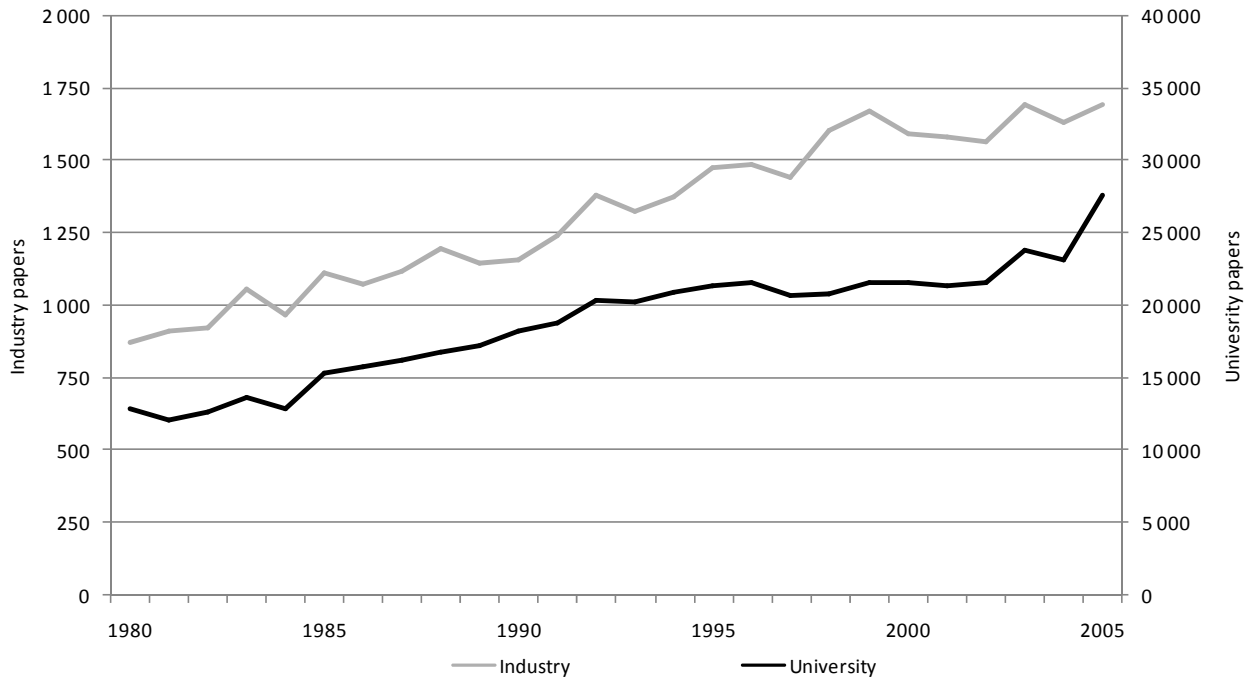
The value of the impact factor of a journal is the number of citations received in a given year by papers published in that journal during the two previous years, divided by the number of papers published in that journal during those two years. It is, in essence, a measure of the short term impact of papers published in a journal. As mentioned earlier, because citation practices are different in each subfield, mean values of impact factors cannot be compared directly among different subfields. In order to take into account these different practices, the average impact factors used in this paper are normalized by subfield and aggregated to form an average relative impact factor (ARIF). This relative impact factor (RIF) indicator is obtained by dividing each paper's impact factor (for example 3)—obtained from the impact factor of the journal in which it is published—by the average impact factor of papers in this particular subfield (for example 6, which would result in an ARIF value of 0.5). RIF values are then computed by aggregating the RIF of each paper and dividing the result by the total number of papers to get the average. When ARIF values are above 1, it means that the papers are published in journals with impact factor values above the world average in their respective subfields; when it is below 1, it is below the world average.

A similar procedure was applied for the field normalization of citations received by papers. Citations to Canadian papers were gathered using as criteria the authors' names, publication years, volume numbers and pages. Citations are counted using a four-year citation window, which means that for papers published in 2000, citations received between 2000 and 2003 are counted. These citations counts are then normalized by the average number of citations received by papers in the same subfield. Like the ARIF, the average relative citations (ARC) values above 1 are above the world average and ARC values below 1 are below the world average of received citations. These two indicators are similar to those developed by Schubert and Braun (1986), Moed, De Bruin and van Leeuwen (1995) and Gingras (1995).

### **Results**

As Figure 1 shows, the number of papers published by Canadian universities and by Canadian industries has increased steadily over the period studied. Among Canadian sectors, the academic and industrial sectors had the highest overall increase, respectively 114% and 94%. While academic publications went from 12,867 in 1980 to 27,597 in 2005, the contribution made by industries went from 872 in 1980 to 1,691 in 2005. Both sectors' share of the Canadian scientific output grew over the period—especially for universities. Indeed, universities' share went from 75.4% in 1980 to 85.4% in 2005. For industries, this increase is less marked. It went from 5.1% in 1980 to 6.5% in 1998 and 1999 but dropped steadily since then to 5.2% of Canadian papers in 2005. As a whole, the number of Canadian publications rose by 89% between 1980 and 2005, passing from about 17,000 to over 32,000.

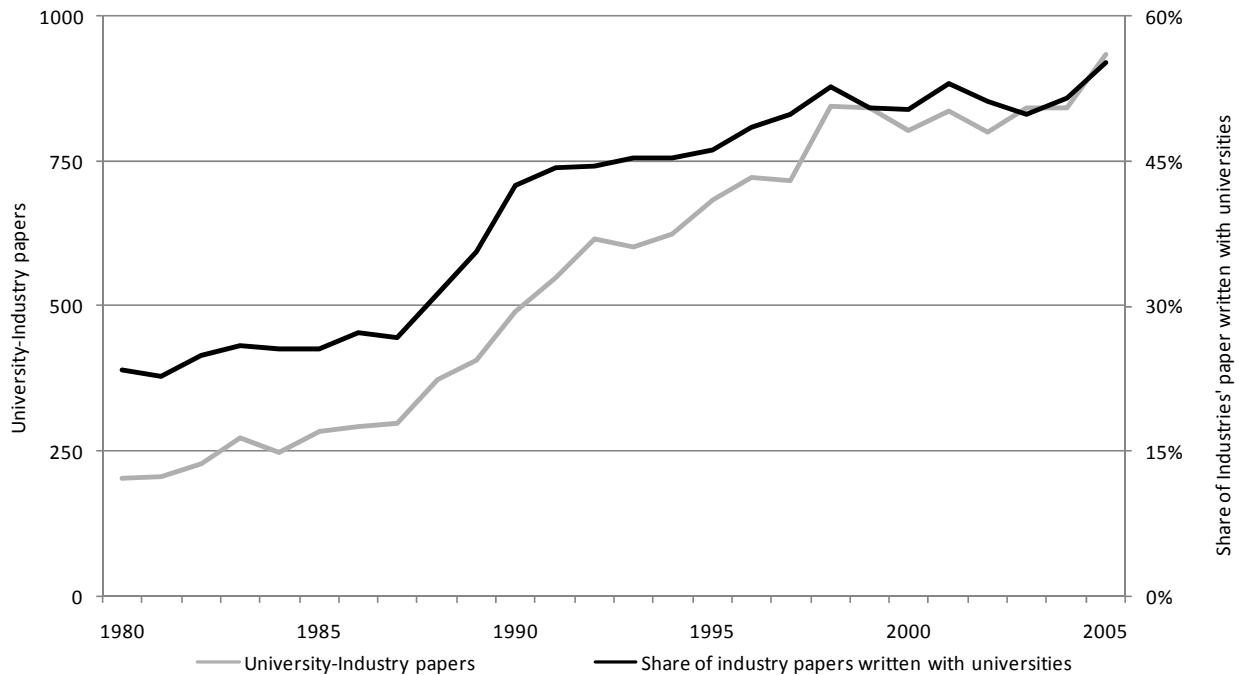
Figure 1. Number of papers written by universities and number of papers written by industries in Canada, 1980-2005



Source: Science Citation Index. Compiled by the Observatoire des sciences et des technologies.

During the same period, the number of publications carried out in university-industry collaborations increased by 360%, passing from 203 to 934 (Figure 2). Their share of the Canadian papers thus went from 1.2% in 1980 to 2.9% in 2005, peaking at 3.4% in 1998. Figure 2 also shows that collaboration with universities progressively accounts for a larger share of industries' papers over the period. Indeed, while less than 15% of industries' papers were written with colleagues in universities in 1980, this share reaches 55% in 2005.

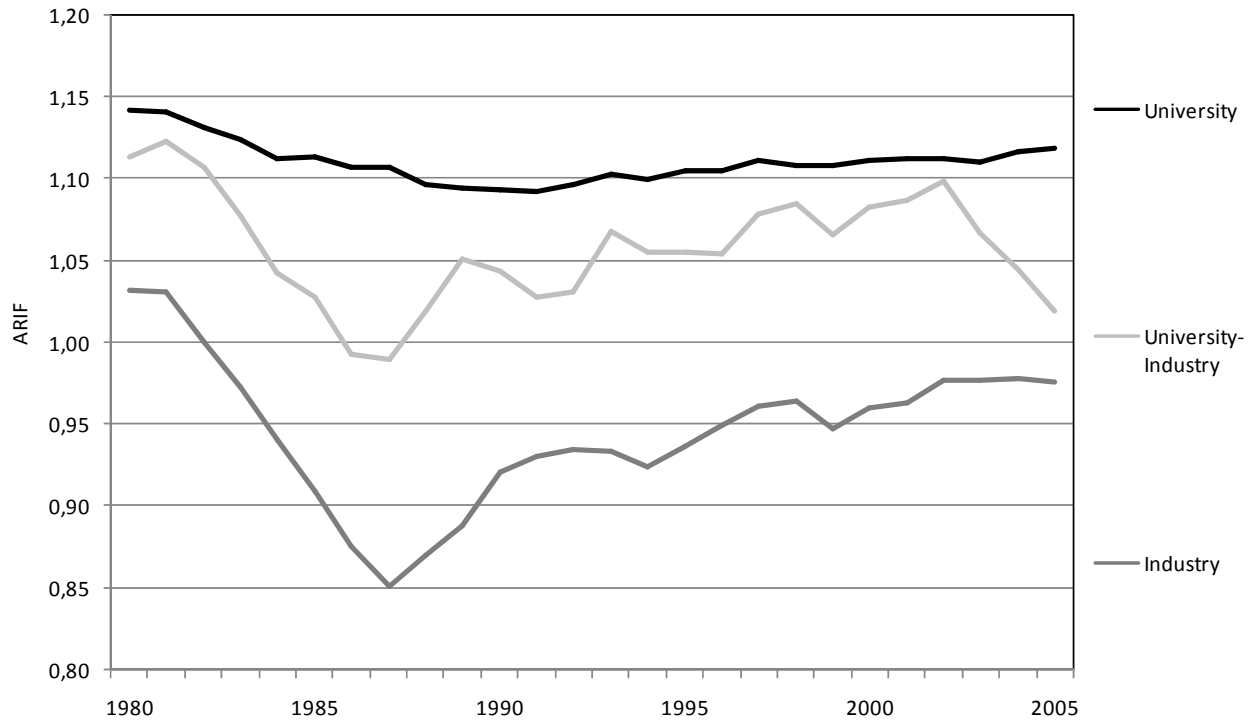
Figure 2. Number university-industry papers and share of industries' papers written with universities, 1980-2005



Source: Science Citation Index. Compiled by the Observatoire des sciences et des technologies.

The previous figures showed that university-industry collaborations in Canada increased in quantity over the last 25 years. But what about the scientific impact of these collaborations? Two measures are used to assess this impact: one based on the impact factor of journals, the other on the citations received by papers over a fixed number of years. Figure 3 presents the average relative impact factor (ARIF) for these collaborations, as well as for university publications and industry publications. We see that the ARIF of academic publications is always higher than that of university-industry collaborations. Though it dropped during the eighties, the ARIF of university publications has been steadily increasing ever since. On the whole, university papers are published in high-reputation journals. Though ARIF values of papers co-authored by researchers in Canadian universities and industries have been increasing steadily between 1988 and 2002, these papers are generally published in lower-reputation journals. Publications written by industries are generally published in journals with impact factor values below the world average. On the whole, these data show that collaboration with universities significantly increases industrial researchers' access to high reputation journals. For universities, however, publishing with industries has the reverse effect and diminishes the ARIF.

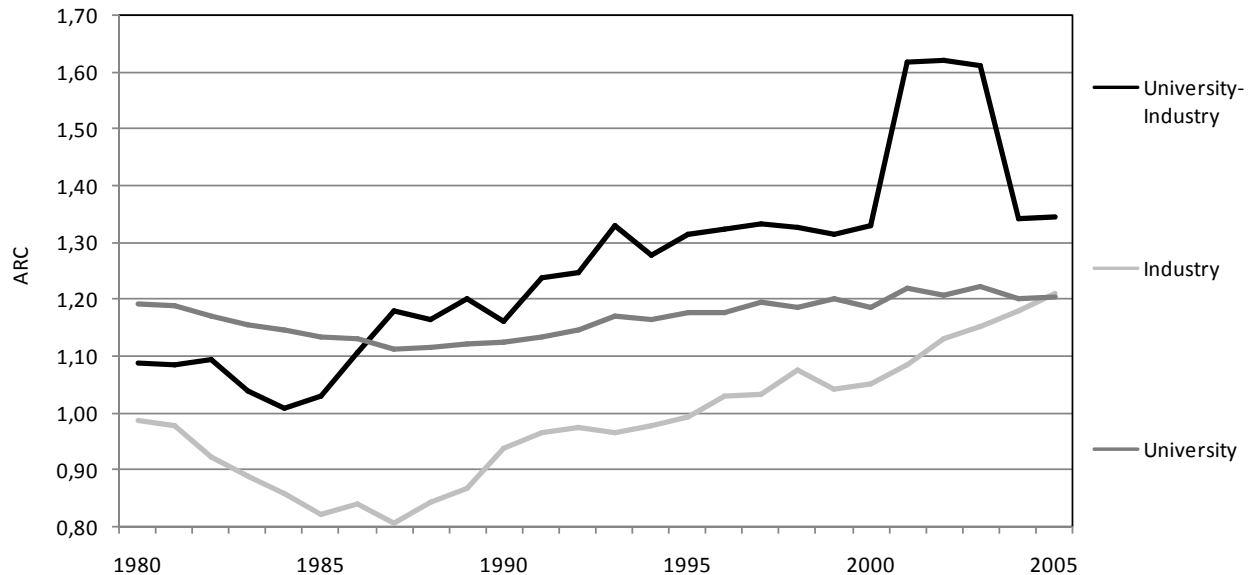
Figure 3. Average of relative impact factor of university papers, industry papers and university-industry papers, 1980-2005 (three-year moving averages)



Source: Science Citation Index and Journal Citation Reports. Compiled by the Observatoire des sciences et des technologies.

Given the limits associated with the use of impact factors, we also measured the direct scientific impact of research using ARC values. Figure 4 show that ARC values follow a different pattern than those of the ARIF. Though the ARC values of university-industry papers were below those of university papers between 1980 and 1986, they have increased since then and are above those of university papers over the rest of the period studied. The ARC of university papers decreased between 1980 and 1987, followed by an increase, but has remained more or less stable since the beginning of the 2000s. The scientific impact of industry papers has also increased steadily since 1988 and, in 2005, was on par with that of university publications.

Figure 4. Average relative citations (ARC) of university papers, industry papers and university-industry papers, 1980-2005 (three-year moving averages)



Source: Science Citation Index. Compiled by the Observatoire des sciences et des technologies.

Table 1 shows the ARIF and ARC of university, industry and university-industry papers by field for the period 2001-2005. It shows that the ARC values of university-industry papers are higher than those of university papers in physics, biomedical research, clinical medicine, chemistry and in engineering. The ARC values of industry papers are also higher than those of university papers in all these fields except engineering. On the other hand, ARC values of university papers are higher than those of industry and university-industry papers in biology, earth and space science and mathematics. In terms of ARIF values, university-industries collaborations are higher than those of university publications in biomedical research, clinical medicine and mathematics. Globally it is in health-related fields that research done in collaboration with industry gets the highest impact in terms of both ARC and ARIF values. This table also strongly suggests that scientific evaluation should use citations received (normalized by fields like ARC) instead of impact factors in order to get a better measure of the real impact of research as opposed to its expected impact provided by ARIF.

Table 1. Average relative impact factors (ARIF) and average relative citations (ARC) of university papers, industry papers and university-industry papers, by field, 2001-2005

Field	ARIF			ARC		
	University	Industry	University-Industry	University	Industry	University-Industry
Physics	1,19	1,01	1,08	1,31	1,33	1,74
Biomedical research	1,07	1,09	1,21	1,01	1,32	1,69
Clinical medicine	1,12	1,07	1,16	1,22	1,40	1,64
Chemistry	1,22	1,07	1,08	1,23	1,24	1,32
Engineering	0,99	0,90	0,97	1,06	1,01	1,19
Biology	1,06	0,91	0,97	1,12	1,00	1,06
Earth and space science	1,06	0,86	0,88	1,19	0,92	0,95
Mathematics	0,99	0,87	1,15	1,06	0,68	0,76

Source: Science Citation Index and Journal Citation Report. Data compiled by the Observatoire des sciences et des technologies.

### Discussion and conclusion

In Canada, the number of publications between 1980 and 2005 rose by 89%. During the same period, universities strengthened their position as the principal producers of new knowledge. In 2005, they contributed to 85.4% of the scientific publications of Canada while the industrial sector represented 5.2% of Canada's publications. Papers co-authored by researchers from the two sectors grew from 1.2% of Canada's scientific production in 1980 to 2.9% in 2005.

The ARIF values of university-industry publications presented in Figure 3 show that these publications are generally published in journals with a lower reputation than those in which university publications appear. The difference between these results and those obtained by Godin and Gingras (2000) is due to the effect of using a normalized indicator for aggregating the different specialties forming a discipline. However, and quite surprisingly, average relative citations (ARC) values for publications involving university-industry collaborations are, since 1987, higher than those of university papers. This means that, though university-industry research is published in journals with lower ARIFs than those of university research, its observed scientific impact is above that of university research. Our results support those Katz and Hicks (1997) and Lee and Bozeman (2005) conclusions that collaborative publications receive higher citation counts than papers without collaborations.

More importantly, our study shows that university-industry collaborations are advantageous to the two partners in terms of scientific impact. Though based on imperfect data, Godin and Gingras' (2000) conclusion still holds true: collaboration with industries is not detrimental to the scientific impact of university research and could, in fact, improve it. Moreover, using field-normalized citation values, we have shown that the observed scientific impact of university-industry collaborations in Canada is higher than that of both university papers and industry



papers. Though papers resulting from university-industry collaborations are, on average, published in journals with *lower* impact factors, they in fact receive, on average, *higher* citation counts than those published without such collaborations.

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### **Note**

1. Among others, the inclusion of journal self-citations, the asymmetry between the numerator and the denominator, the skewness of the distribution of citations received by papers published in a given journal and the use of a two-year citation window. For a review of impact factors' limits, see Archambault and Larivière (2007). Given these limits, this paper does not use the impact factor of a journal as a measure of the *average* impact of the papers it publishes, but rather as a proxy for the "relative international eminence of journals", the latter being closely correlated to impact factors (Vinkler, 2004).

### **Bibliography**

Archambault, É and V Larivière 2007. Origins of measures of journal impact: historical contingencies and their effect on current use. In *Proceedings of the 11th International Conference of the International Society for Scientometrics and Informetrics (ISSI)*, eds Torres-Salinas, D and H F Moed, pp. 45-51, Madrid: CSIC.

Gibbons, M, C Limoges, H Nowotny, S Schwartzman, P Scott, and M Trow 1994. *The new production of knowledge: the dynamics of science and research in contemporary societies*. London: Sage.

Godin, B, Y Gingras 2000. Impact of collaborative research on academic science. *Science and Public Policy*, 27(1), 65-73.

Gingras, Y 1995. Performance Indicators: Keeping the Black Box Open. *Proceedings of the second International Symposium on Research Funding*, Ottawa, pp. 45-49.

Katz, J S, D Hicks 1997. How much is a collaboration worth? A calibrated bibliometric model. *Scientometrics*, 40(3), 541-554.

Katz, J S, B R Martin 1997. What is research collaboration? *Research Policy*, 26(1), 1-18.

Lee, Y S 1996. 'Technology transfer' and the research university: a search for the boundaries of university-industry collaboration. *Research Policy*, 25(6), 843-863.

Lee, S, B Bozeman 2005. The impact of research collaboration on scientific productivity. *Social Studies of Science*, 35(5), 673-702.

Leydesdorff, L, H Etzkowitz 1996. Emergence of a triple helix of university-industry-government relations, *Science and Public Policy*, 23(5), 279-286.

Lindsey, D 1980. Production and citation measures in the sociology of science: the problem of multiple authorship. *Social Studies of Science*, 10(2), 145-162.

Moed, H F, R E De Bruin, Th N van Leeuwen 1995. New bibliometric tools for the assessment of national research performance: Database description, overview of indicators and first applications. *Scientometrics*, 33(3), 381-422.

OCDE 1999. *Industry Science Relations*, Paris: OCDE Publications.

Schubert, A, T Braun 1986. Relative indicators and relational charts for comparative assessment of publications output and citation impact. *Scientometrics*, 9(5-6), 281-291.

Vinkler, P 2004. Characterization of the Impact of Sets of Scientific Papers: The Garfield (Impact) Factor. *Journal of the American Society for Information Science and Technology*, 55(5), 431-435.