The Importance of Bilateral and Multilateral Differentiation in the Assessment of International Collaboration - a case study for Austria and six countries

Juan Gorraiz[1], Ralph Reimann[2] and Christian Gumpenberger [1]

[1] *juan.gorraiz@univie.ac.at, christian.gumpenberger@univie.ac.at*
University of Vienna, Vienna University Library, Bibliometrics Department, Boltzmanngasse 5, A-1090 Vienna, (Austria)
[2] ralph.reimann@boku.ac.at
University of Natural Resources and Life Sciences, Gregor Mendel Straße 3, A-1180 Vienna (Austria)

Abstract

This bibliometric study on the collaboration of Austria and six target countries (Slovenia, Hungary, Czech Republic, Denmark, Switzerland and Israel) reveals the importance of differentiation between the bilateral and multilateral contingents in the assessment of international scientific collaboration. For this purpose a "degree of bilaterality" (DB) and a "citation degree of bilaterality" (CDB) are introduced. In our findings the DB and the CDB have values lower than 1/3 and 1/5 respectively. Therefore, the total collaboration is mostly shaped in its volume and impact by the multilateral contingent.

The results prove the necessity for differentiation. This approach gives a more complete and concise picture of the volume and impact of international collaboration on country level. It is therefore of strategic value for the consideration of future partnerships.

Regarding the impact estimation of the collaboration publication output, a multi-faceted approach was used. Apart from basic indicators it furthermore included un-citedness, excellence and field citation averages by the introduction of domestic and collaborative Crown Indicators.

Introduction

According to the development from "little science" to "big science" and more recently to "e-science", the importance of international scientific collaboration has increased permanently (Beaver, DD., 2001). From the early 70s up to the 80s, the fraction of internationally co-authored papers – one of the most usual measures for collaboration – has doubled (Luukkonen, T. et al., 1992). More recent studies confirm a similar trend by reporting an intensifying collaboration for all fields at practically all aggregation levels (Glänzel, W. 2001; Persson, O. et al. 2004). The volume of international collaboration increased between 1996-2000 and 2001-2005 significantly across all countries and disciplines (30% for France, 50% UK, > 100% China). Furthermore the volume of international cooperation increased more rapidly than at domestic level (Adams, J., 2007).

International scientific collaboration is perceived as an enhancement of a country's scientific capabilities and is also considered as useful for cost sharing (Luukkonen, T. et al., 1993). Thus, globalisation of science demands new and adequate science policy measures at national and supranational levels (Gomez I. et al, 1999). Endorsement by explicit policies allows access to a wider range of facilities and resources and therefore contributes to higher impact of the research output.

The apparent conclusion, that international scientific collaboration is particularly advantageous for less advanced countries, but also beneficial for highly industrialised countries, is generally accepted (Glänzel, W., 1999). More recent studies suggest further factors like physical proximity of collaborators as a strong predictor of the collaboration impact (Lee et al, 2010). Adams reported that the average impact of internationally co-authored work is significantly higher than the overall average, and all the analyzed countries gain from collaboration (in this case with the UK) in terms of impact - especially in biomedical sciences (Adams, J., 2007; Roberts, G. 2006).

However, impact improvement, closely related to research excellence, should not be the only reason for setting up collaborations. They are also about gained knowledge of different research systems and the build-up of strategic partnerships. Each country has its very own specific portfolios, policies, priorities and objectives to derive advantage from as cooperative partner.

This is a bibliometric analysis of the estimated volume and impact of Austrian collaboration with six targeted countries. In order to examine existent partnership strategies and to develop new ones, following issues were emphasized:
1) Most studies about scientific collaboration among countries show no distinction between "bilateral" (i.e. only 2 countries appear in the "affiliation" field) and "multilateral" (i.e. more than 2 countries listed in th "affiliation" field) collaboration. This carries the danger of false interpretations. For example, the "total" collaboration between Austria and (a fictitious) "Kakania" could have a very high impact but only due to the collaboration with other countries (USA, Germany, UK, etc.) in their "multilateral" cooperation. The impact of the "bilateral" cooperation could in fact remain below the domestic non-cooperative level of the single country (Austria only or "Kakania" only).
One of the principal aims of this study was to analyse these different types of collaboration in detail and to find out about their proportions and correlations.
2) Citation counts for research papers are a good indicator for collaboration impact, however, normalisation is needed to reflect discipline per publication year (see Glänzel's "Relative Citation Rate RCR" or Adam's version "ReBased Impact (RBI)").
The company *Evidence* developed a methodology called "*Impact Profile*^{TM}" to overcome the skewness distribution problems in research performance data (Adams J, Gurney K A and Marshall, S., 2007).
In our study we opted for a multi-faceted approach using the usual indicators (citations, citations per publication,) and incorporating normalised citation counts by calculating "domestic and collaborative Crown Indicators" (see Methodology). The consideration of the skew citation distribution was realised by retrieving the proportion of un-cited and highly cited papers.

Methodology

Countries

Besides Austria, five European countries - Slovenia, Czech Republic, Denmark, Hungary, Switzerland - and Israel, were selected according to specific national portfolios and strategies to analyse the volume and impact of existent partnerships and to develop new strategies. Austria has been chosen as a focal point of the collaboration with three highly developed countries from different geographical regions (DEN from Scandinavia , CH from Central Europe and ISR from the Middle East) balanced by additional three scientifically emergent neighbouring countries (HUN, CZE, SLO).

Definitions

Co-affiliated publications are likely to provide meaningful data for monitoring "cooperation" or "collaboration" among countries, although there will always be collaborations that do not result in co-affiliated papers, or co-affiliated papers which may have required only limited collaboration or no collaboration at all. Multiple affiliations are automatically considered as cooperation and could distort the results as well. But unfortunately, alternative data-based approaches, e. g. using information about co-funding or international exchanges, have serious

limitations in terms of their availability and validity, and were therefore out of the scope for this study.
In our analysis, all publications are considered as "total collaborations", where the "affiliation" field at least contains Austria and one of the targeted countries. Publications including only Austria and one single targeted country are called "bilateral", whereas publications containing additional targeted countries are indicated "multilateral". Due to the authors' understanding "domestic" publications are all the single affiliation publications, i.e. the "Affiliation" field either exclusively contains Austria (Austria only) or one of the selected cooperation countries (country only).

Data

The analysis was performed in Web of Science (including the "Proceedings" part). Eight publication years were considered (1999-2006). Publications exclusively belonging to the area "Arts & Humanities" were not considered, because their coverage representation in this database is very low and their impact estimation would only distort the general results.
About 270.000 publications were retrieved and their impact was assessed according to different indicators (see Results – Volume). Only publications of the three most important document types (Article, Review Articles & Proceedings Papers) were considered. This approach allowed a later impact estimation based on standards like the ESI averages and percentiles. The chosen citation window for this analysis was June 2010.
Four main subject areas or clusters - namely Life Sciences, Natural Sciences, Social Sciences and Multidisciplinary - were analysed separately. Using a more granular classification was not practicable due to the small number of publications available for some of the considered collaboration types.

Indicators

A) Volume of the collaboration

The volume of the collaboration was measured by the number of publications, P (normal count, no fractional count).

B) Impact of the collaboration

The impact of the collaborative publications was measured, as usual in bibliometric studies, by the total number of citations (C) and the average citation rate (or citedness), number of citations per publication (CPP).
The "gained impact" of the collaborative publications was estimated by the increase in the average citedness (CPP) of internationally co-affiliated publications (bilateral, multilateral or total) in comparison to the average value of the domestic production (country only). Thus, a "citation gain", CG = (CPP coop – CPP country only) / CPP country only) was calculated for each type of collaboration.
Obviously, this indicator neither considers the different field citation behaviours nor the dependence on the publication year nor the skewness of the citation distribution. In order to overcome all these "classic" problems and to give a more accurate and complete impact estimation of the collaborative publications, we used a multi-faceted approach based on the following three indicators:
1) Number of un-cited publications (UCP)
2) We calculated a "Domestic Crown Indicator" (DCI) as well as a "Collaborative Crown Indicator" (CCI) - an amended Crown Indicator (Moed, H. 2010) - as the average of the field-normalized citation-rates. Therefore, the total number of received citations of each publication was field-normalized by using the world average citation rate of the relevant field and of the

relevant year of publication (according to 'Essential Science Indicators' by Thomson Reuters). Finally, the average of the list of the field-year-normalized citation rates was calculated.
3) Number of highly cited publications, a rating for the contribution of collaboration to research excellence. For this study we defined an "excellence range" considering all publications belonging to at least the Top 10%. The identification of these publications was performed according to the percentiles from the analytical tool "Essential Science Indicators" (ESI) from Thomson Reuters.

Results

1. Volume or intensity of the collaboration.

The main results are shown in Table 1.
Switzerland shows the highest volume of collaboration, Israel the lowest.

Table 1. Volume (number of publications, P and %) of the different collaboration types between Austria and six target countries

Publications	*Country only P*	*bilateral collaboration P (%)*	*multilateral collaboration P (%)*	*total collaboration P*
Austria	39.609	---	---	---
Slovenia	11.096	198 (28,25%)	503 (71,75%)	701
Czech R.	29.006	382 (33,07%)	773 (66,93%)	1.155
Hungary	21.448	432 (42,69%)	580 (57,31%)	1.012
Denmark	37.479	193 (19,48%)	798 (80,52%)	991
Switzerland	64.811	907 (29,21%)	2.198 (70,79%)	3.105
Israel	56.109	121 (27,13%)	325 (72,87%)	446

A "degree of bilaterality" (DB, amount of the bilateral component in the total collaboration in %) is also introduced and calculated for each country.
Except for Hungary (DB about 43%), where not only geographical but also historical connotations play a significant role, the DB varies from 1/4 to 1/3 at most. Therefore, the multilateral collaboration (more than 2/3) in principal determines the volume of the total cooperation in all our case studies.

Figure 1 shows an analysis of the most usual partners of the multilateral collaboration. In case of Slovenia, five countries (USA, Poland, Switzerland, Russia and Germany) account for more than 60% of the volume of its multilateral collaboration with Austria. High values with several countries indicate a strong participation in large international collaborations.
For all the six targeted countries, the 10 most active partners (USA, Germany, England, France, Italy, Switzerland, Poland, Spain, Netherlands and Russia) also belong to the most

developed countries and certainly shape the attributes of this collaboration type. Interestingly, there is a weak presence of Asian countries (except for the collaboration with Slovenia, where Japan, Taiwan, China and South Korea cooperate with 36,58%, 34,99%, 34,39% and 33,80% respectively) and developed countries from other continents, e.g. Canada or Australia. The only "non-expected" partner is Poland with a surprisingly active participation. The presence of Switzerland is not surprising and can be explained by the strong internalization of Swiss research and its high impact in almost all disciplines. This factor increases Switzerland's attractiveness as potential collaborator (Reckling, F., 2007).
The low values for Hungary in comparison to Slovenia and the Czech Republic are notable.

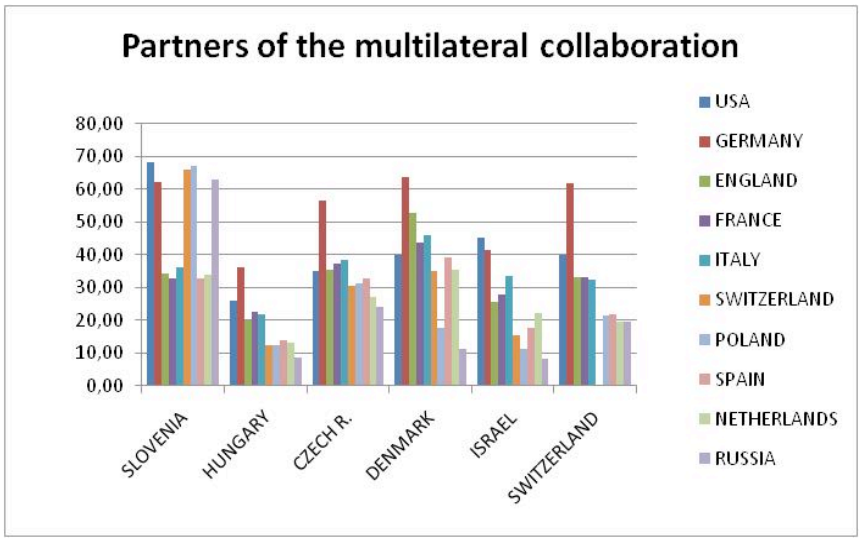

Figure 1. Partners of the multilateral collaboration between Austria and the six targeted countries

A more detailed analysis of the multilateral contingent (see Figure 2) demonstrates the interactivity of the considered countries as collaboration partners with Austria. In our case study, only the network Slovenia/Czech Republic has some considerable size.

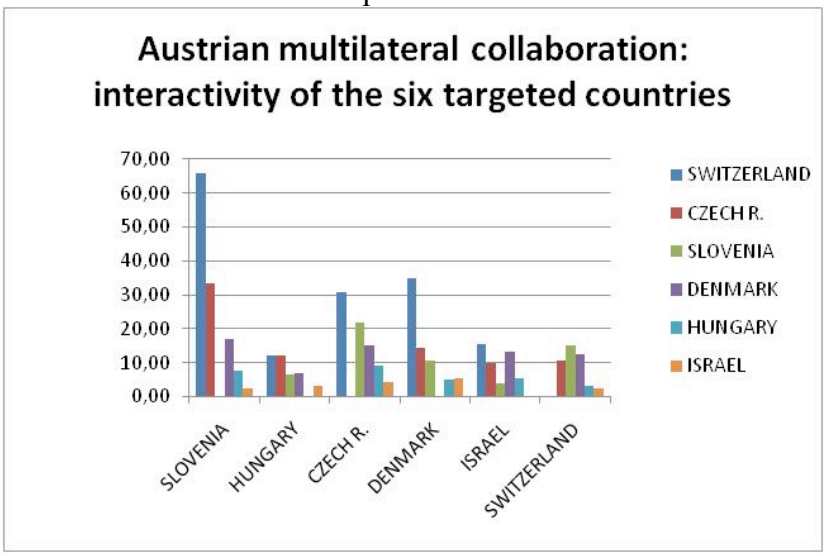

Figure 2. Interactivity of the six targeted countries in the Austrian multilateral collaboration

Figures 3a and 3b show that the timelines of the bilateral and the total collaboration are quite different, except for already mentioned Hungary.

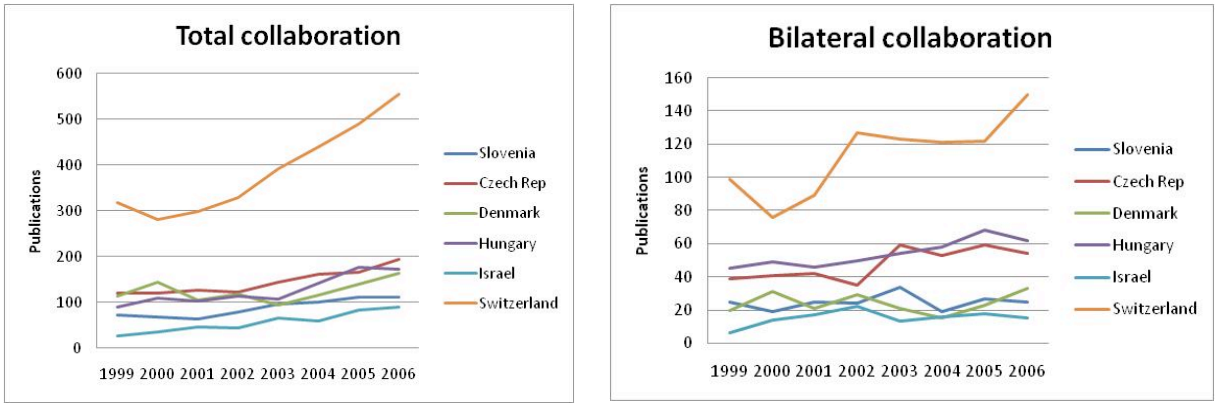

Figure 3a and 3b. Timelines of the total and the bilateral Austrian collaboration.

2. Impact of the collaboration

As already mentioned in the introduction and methodology parts of this article, the impact of the collaboration has been estimated by using a multi-indicator approach including following indicators (see also Methodology):

A) Total number of citations (C)

Table 2 shows the total number of citations for each type of collaboration.

An analogue "citation degree of bilaterality" (CDB), a measure of the proportion of citations of the bilateral component to the citations of the total collaboration in %, is also introduced and calculated for each targeted country.

Table 2. Impact (total number of citations, C and %) of the different collaboration types between Austria and six target countries.

Publications	*Country only C*	*bilateral collaboration C (%)*	*multilateral collaboration C (%)*	*total collaboration C*
Austria	425.222	---	---	---
Slovenia	59.673	2.045 (14,24%)	12.314 (85,76%)	14.359
Czech R.	166.859	4.764 (19,73%)	19.380 (80,27%)	24.144
Hungary	137.371	4.793 (27,83%)	12.432 (72,17%)	17.225
Denmark	574.469	3.833 (10,50%)	32.646 (89,50%)	36.479
Switzerland	1,021.568	18.028 (19,45%)	74.651 (80,55%)	92.679
Israel	639.436	1.806 (11,66%)	13.678 (88,34%)	15.484

In our study the CDB is significantly lower than the DB and always remains below 20% (1/5), except for Hungary (27,9%). For three countries the CDB is even less than 15%.

Therefore the impact of the total collaboration is strongly determined by the multilateral contingent.
Obviously in five of the six studied cases, the impact of the collaboration is almost exclusively determined by the multilateral contingent.

B) Citations per Publication (CPP)
The results are shown in Figure 4.

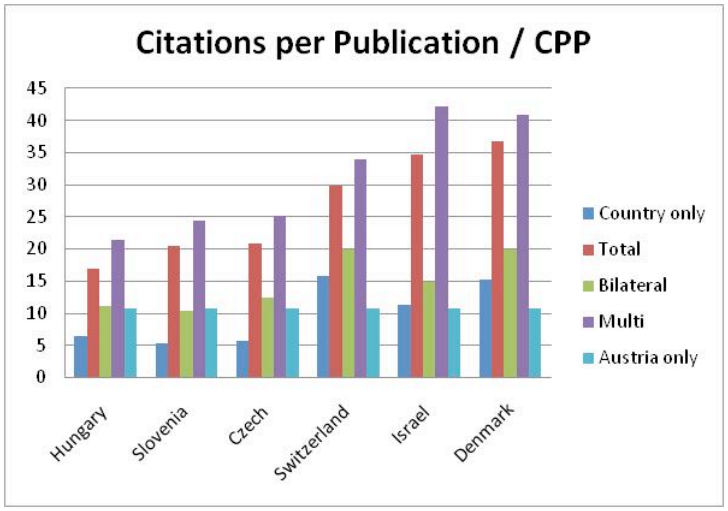

Figure 4. Average citation rate (CPP) for each type of collaboration

Considering the total collaboration, the one with Denmark shows the highest absolute citedness, followed by the ones with Israel and Switzerland. The citedness of the total collaboration with the former communist countries, Hungary, Slovenia and the Czech Republic, is also higher than the domestic ones but mostly due to their multilateral component. Considering the bilateral collaboration, Denmark and Switzerland share the first place, doubling the Austrian domestic values.

C) Citation Gain.
The unit of measurement for the citation gains is a percentage.

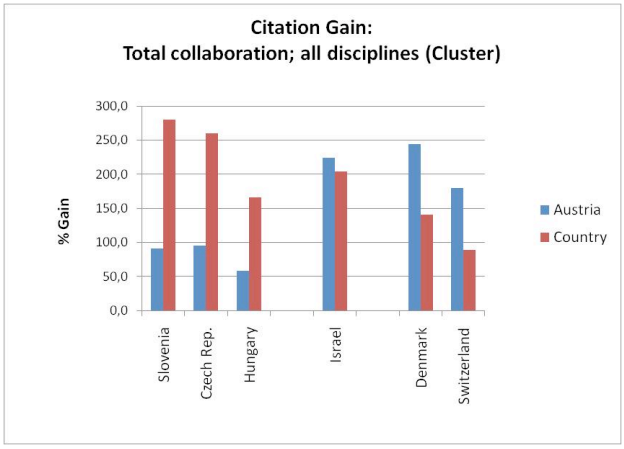

Figure 5. Citation gains (CG) of the total collaboration

Considering the total collaboration, there is a citation gain for all countries (Figure 4) in agreement with previous studies, showing that international scientific collaboration is particularly advantageous for less advanced countries, but also beneficial for highly

industrialised countries. In our study, Austria benefits from Denmark and Switzerland, whereas Slovenia, Hungary and the Czech Republic profit by Austria (Glänzel, W., 1999; Adams, J., 2007).

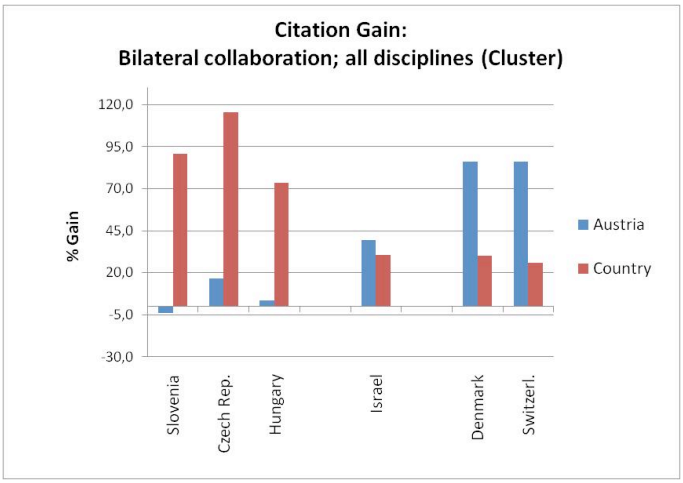

Figure 6. Citation gains (CG) of the bilateral collaboration

A quite different picture is obtained when only considering the bilateral collaboration (see Figure 6). Whereas the collaboration with Slovenia results in no citation gain for Austria, only an insignificant benefit can be seen in the collaboration with Hungary.

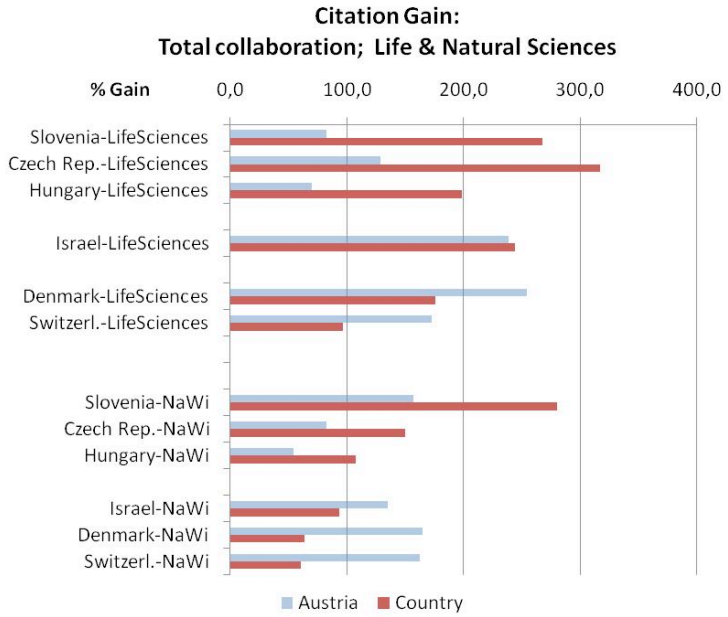

Figure 7. Citation gains (CG) of the total collaboration for the areas "Life and Natural Sciences"

Considering different sub-disciplines like "Life and Natural Sciences" (as defined in Methodology →see Figures 7 and Figure 8) allows for a more precise differentiation. This approach illustrates the dependence on the research areas. Gains naturally vary according to the specific research focuses of each country.

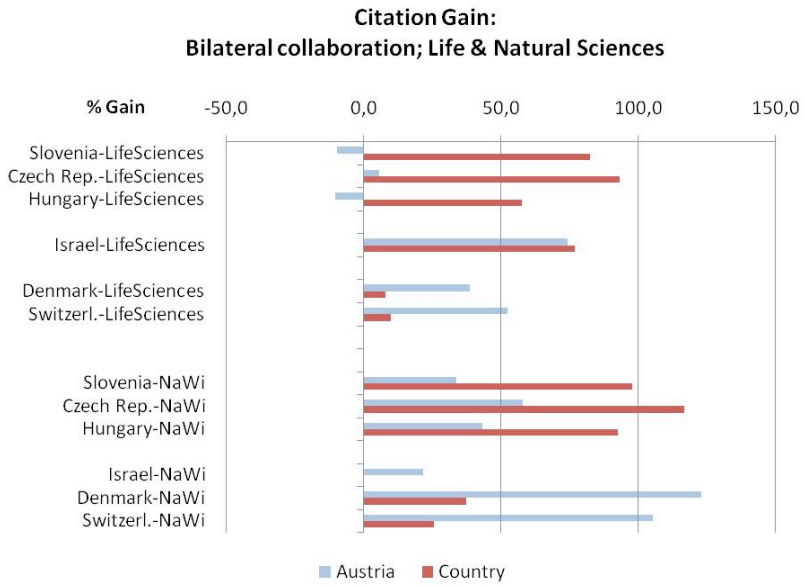

Figure 8. Citation gains (CG) of the bilateral collaboration for "Life and Natural Sciences"

In the research area "Life Sciences", the bilateral collaboration of Austria with Slovenia and Hungary results in no citation gain and remains considerably under the domestic level

D) Number of un-cited Publications (UC)
The number of un-cited publications was counted for each type of collaboration. Their percentage (%) (UC/P*100) is shown in Figure 9.

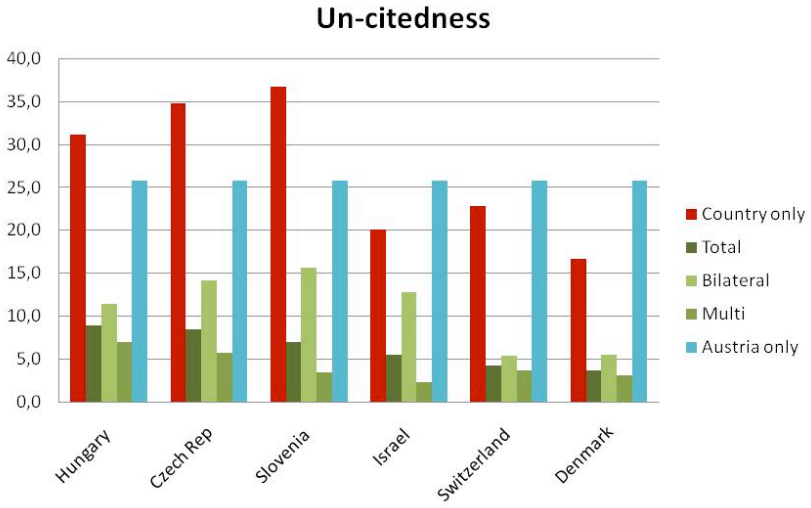

Figure 9. Proportion of un-cited publications (UC %) for each type of collaboration

Considering un-citedness, each type of collaboration brings a big improvement. Co-affiliated publications are more likely to be cited, probably due to the work's wider exposure to the scientific communities in each country.

Even the bilateral collaboration with Hungary, the Czech Republic, Slovenia and Israel shows a reduction of almost the half of un-cited publications in comparison with the Austrian-only publications (percentage). In case of Switzerland and Denmark the reduction amounts to about 1/5. For these two countries and for Hungary the differences in un-citedness for either total or bilateral publications are relatively low. For the other targeted countries, the bilateral collaboration has a double-digit percentage of un-citedness in comparison to the total one.

E) Crown Indicator (CI)
The results are shown in Figure 10.
All countries by themselves - except for Switzerland (1,29) and Denmark (1,16) - have a DCI (Domestic Crown Indicator) lower than the world average (=1). The CI of the bilateral collaboration remains below the world average only for Hungary (-7,4%), has average values for Slovenia (2,5%), and remains above the world average for the Czech Republic (13,4%) and Israel (+36,3%). Denmark (95,1%) and Switzerland (90,8%) have the highest values. Bilateral collaboration always results in a CI higher than the DCI (domestic values).

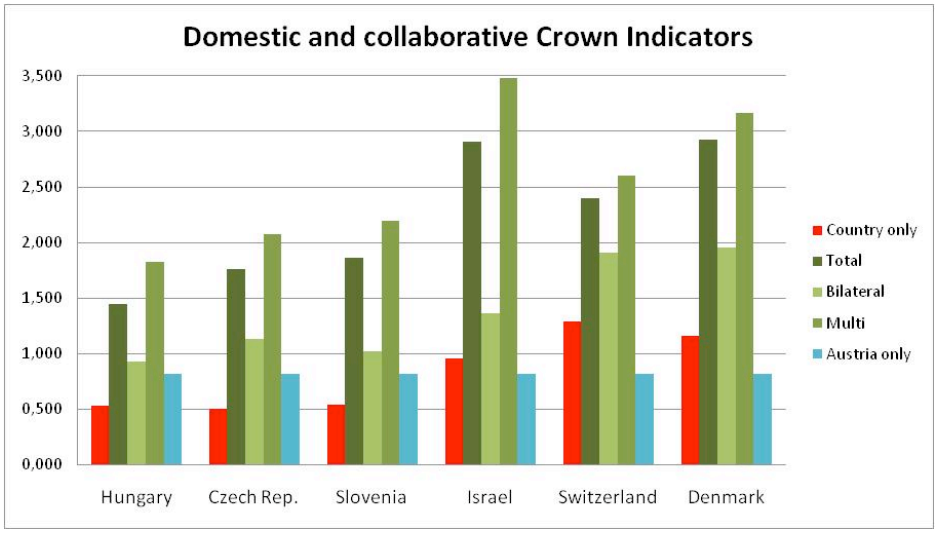

Figure 10. Collaboration and Country Crown Indicators

Considering total collaboration, Denmark retains its top position (+192,8%), followed by Israel (+190,4 %, the country that profits most from the multilateral part) and Switzerland (+140%), whereas Slovenia and the Czech Republic switch places with CI values of +86,2% and +76,1% respectively.
Hungary is the bottom of the CI league with +44,3%.

F) Excellence (HCP)
The number of highly cited publications, belonging to at least the Top 10%, was retrieved. Their proportion (in %) is shown for each type of collaboration in Figure 11.
All types of collaboration increase the proportion of excellent publications as defined in this study (Top 10%).
Considering the skewness of the citation distribution by analyzing the percentage of top highly-cited publications has no influence on the ranking of the targeted countries in regard to total collaboration (compare figures 3 and 9). However, there are some significant differences regarding the bilateral contingent. Figure 10 shows that the bilateral collaboration with Slovenia includes a higher percentage of “excellent” publications than the domestic Austrian

performance (Austria only). Considering HCPs, the bilateral collaboration with Slovenia even outperforms the one with Hungary.
Israel considerably benefits from both types of collaboration.

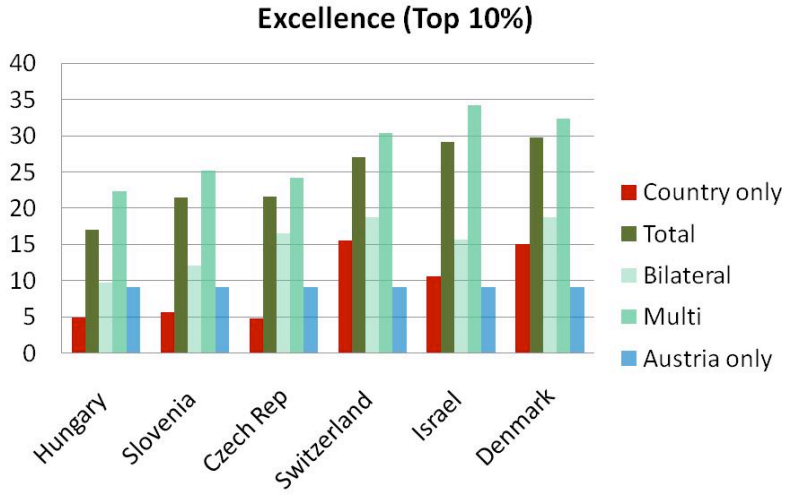

Figure 11. Proportion of excellent publications (%) for each type of collaboration.

Conclusions

A differentiation of the bilateral and multilateral components is certainly necessary when assessing international scientific collaboration. Separate analysis of bilateral and multilateral contributions allows for a more complete and concise picture of the international collaboration between countries. This could be highly beneficial for the examination of either existent or future partnership strategies.
In our case study, the "degree of bilaterality" (DB) and the "citation degree of bilaterality" (CDB) have values lower than 1/3 and 1/5 respectively. As a conclusion, the total collaboration is mostly shaped in its volume and impact by the multilateral contingent.
If bilateral co-affiliated publications can only reflect national collaboration portfolios and strategies to some extent, then multilateral publications are even more dubious for this purpose. A considerable part of them merely reflects the participation in large international projects.
On the other hand, favouring only large international (multilateral) collaborations instead of bilateral ones may not be an adequate solution either. Bilateral collaborations could additionally function as a "door opener" for the participation in larger cooperation projects.

In our study, geographical proximity does not better the situation regarding the impact of the studied collaboration types.

Our multi-faceted approach reinforces the necessity of not only using "rebased" citation data for the bibliometric impact estimation of collaboration. It is also crucial to separately analyze the following three aspects: the un-cited range, the average range and the excellence range. All three approaches correlate very well in our study and corroborate the findings from the CPP analysis. The only outlier is the bilateral collaboration with Slovenia. According to CPP the Austrian-Slovenian cooperation would result in a negative citation gain (compared to

Austria-only). However, our separate analysis of the before mentioned three aspects also proved gained impact for this bilateral collaboration.

Another plausible explanation of the results is the more general and simplified assumption that publication's citedness almost only depends on the number of affiliations. Thus domestic publications are obviously less cited than bilateral ones, and the latter again less cited than multilateral ones. Although this effect should only be appreciable at low citation levels it could nonetheless challenge many of the existent bibliometric assessments on the impact of international collaboration. For this reason the authors plan to tackle this issue in a more detailed follow-up analysis.

Finally, it has to be stressed that a bibliometric analysis of the volume and impact of co-affiliated publications can only be a quantitative approach to assess the performance of an international scientific collaboration (ISC): It is certainly helpful to demonstrate features and trends. However, ISC is influenced by multiple complex factors (including qualitative ones), which should also be taken into account for science policy purposes.

Acknowledgments

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