An Informetric Assessment of Various Research Fields Interactions on Base of Categorized Papers in Dimensions

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Abstract

We estimated the level of interactions between all the pairs of the research groups and between all the pairs of the research divisions for 4 five-year periods on base of Dimensions data. The level of interactions is assessed by Jaccard index. Paired interaction for research divisions shows that every consecutive five-year period has decreased irregularity of its distribution of interaction. Cumulative interaction shows that all research divisions tend to have their stickiness index decreased over time. Paired interaction for research groups showed the same results but difference between two consecutive periods is greater by a larger factor. On base of interacting assessments we identified 5 research groups that have been suspiciously assigned to divisions in ANZSRC. Identified research groups have more similar research groups in concurrent divisions with statistically significant level. Those 5 research groups also have strong semantic ties with concurrent divisions, this can be an argument for adapting of ANZSRC.

Keywords [1]

Informetrics, research group, research division, interactions, interdisciplinary, Dimensions, ANZSRC, Jaccard index, stickiness index, distribution, categorization.

1. Introduction

Interdisciplinarity is a fashion direction in modern education and science. Inter-disciplinarity is impossible without interactions between research from various fields. For quantitative assessment of level of interdisciplinarity, of level different research fields interactions a lot of approaches are proposed in recent years.

Currently the most widely used approaches to quantitative measuring of interdisciplinarity use bibliometrics. They take into account co-authorships, collaborations, references, citations and co-citations. The most common bibliometric technique for measuring inderdisciplinarity is some kind of citation analysis. A citation environment is defined as all journals that cite or are cited by a specific journal [1].

In [2] authors measure interdisciplinarity by relating papers' cited journals to their corresponding subject categories of Web of Science. Their metrics take into account the inter-relatedness of subject categories. They use the following quantities deducted from citation of papers of a single subject category: number of papers published in journals associated with this subject category; number of cites by these papers to papers in journals associated with this subject category; number of cites to these papers by papers in journal associated with this subject category.

Another approach based on citations is presented in [3]. It shows that the fraction of paper references that point to work in other disciplines is increasing in both the natural and the social sciences and the fraction that points to another specialty in the same discipline has a slight decline. The

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measures are done using variety – the spread of references across disciplines and disparity – the "intellectual distance" between disciplines in references. The key results they concluded is that interdisciplinarity research takes time to have an impact and that some fields as well as countries are more interdisciplinary than others.

A slightly less used approach for measuring interdisciplinarity using bibliometric uses collaborations. In [4] authors used graph of collaboration between researches to investigate the interdisciplinarity of scientific fields. They estimate similarity between science categories using text similarity between their descriptions. Their measure of interdisciplinarity is based on Stirling's diversity index.

Some of the studies use text analysis to quantify the interaction and evolution of scientific disciplines. In [5] authors compare different measures of dissimilarity between scientific fields. These measures are based on expert classification, citations and information theory.

All the above mentioned approaches require large information resources. Methods that based on citation analysis, are pretty inertial. It is impossible to assess interdisciplinarity of a new paper instantly, because citations take time to take place. As opposed to the mentioned approaches, paper [6] proposed a new technique to assess the similarity between research fields. The technique applies to information resources of Dimensions with already categorized research papers. Dimensions was launched in 2018 and many researchers started using it immediately for bibliometric research [7, 8, 9, 10]. Dimensions uses hierarchical system of research classification, included divisions at high level and research group at low level. In paper [6] similarity of research groups is assessing via Jaccard index.

The current paper extends idea of [6] in the following directions: 1) assessing the research interactions at the high level – at level of divisions; 2) assessing the interdisciplinarity at the low level taking into account only interactions with research groups from different divisions according to arguments of [11] about various impacts for interdisciplinarity levels for various combinations of research fields; 3) improving the research classifying system on base of actual statistics of research fields interactions. Analysis of the research interactions is carried for 4 five-year periods on base of papers dated 2001–2020.

2. Research Classification System Used in Dimensions

Dimensions uses two-level version of ANZSRC. There are 22 research divisions at high level with 157 groups at low level. For example, division *08 Information and Computing Sciences* contains the following research groups:

0801 Artificial Intelligence and Image Processing;
0802 Computation Theory and Mathematics;
0803 Computer Software;
0804 Data Format;
0805 Distributed Computing;
0806 Information Systems;
0807 Library and Information Studies;
0899 Other Information and Computing Sciences.

Dimensions has indexed over 110M research papers. Each paper is assigned to one or several research groups. Such categorization is carried out in by Dimensions itself by special software based on machine learning guided by topic experts [12]. As training data Dimensions uses title and abstract of the paper for this categorization.

3. Interaction between research divisions

Based on Dimensions data we can retrieve a number of papers assigned to each research division. At the same time, we can get the number of above-mentioned papers that were assigned to several research divisions simultaneously. By using this information we assess the interaction of any pair of research divisions using 2 queries. According to [6] we use Jaccard index for assessing the interactions of two research divisions *A* and *B* as follows:

$$S(A, B) = \frac{N_{A \cap B}}{N_A + N_B - N_{A \cap B}},$$

where N_A is a number of papers in division *A*;

N_B is a number of papers in research division *B*;

$N_{A \cap B}$ is a number of papers assigned to divisions *A* and *B* simultaneously.

For example, there are 353 347 papers assigned to division *08 Information and Computing Sciences* in 2019, and 11391 of them also belong to division *17 Psychology and Cognitive Sciences*. Division *17* consists of 178 156 papers published in 2019. Hence, the quantitative assessment of interaction of these divisions is $S(08,17) = \frac{11391}{353347 + 178156 - 11391} = 0.021$.

Jaccard index distributions for two research divisions within the four of the five-year periods are shown in Figure 1. The x-axis corresponds to ranked list of pairs of divisions sorted ascending for each period separately. The y-axis corresponds to their level of interaction plotted in log scale. Overall, we analyzed 231 pairs of divisions. Figure 1 shows that every consecutive five-year period has decreased irregularity of its distribution of interaction. We can see that by observing that pairs of divisions from the beginning of Jaccard index distribution has their interaction decreased over time and the pairs at the end of the distribution on the contrary – increased. This observation is confirmed by Gini coefficient that decreases in time in the following way:

$Gini_D(2001 \div 2005) = 0.739$;

$Gini_D(2006 \div 2010) = 0.737$;

$Gini_D(2011 \div 2015) = 0.733$;

$Gini_D(2016 \div 2020) = 0.733$.

Also, we observe decrease of $\gamma_D = \frac{mean\,(\forall S \in Q_4)}{mean\,(\forall S \in Q_1)}$ – ratio of mean value of Jaccard indexes from the fourth and the first quartiles as follows:

$\gamma_D(2001 \div 2005) = 434.9$;

$\gamma_D(2006 \div 2010) = 372.1$;

$\gamma_D(2011 \div 2015) = 288.1$;

$\gamma_D(2016 \div 2020) = 250.7$.

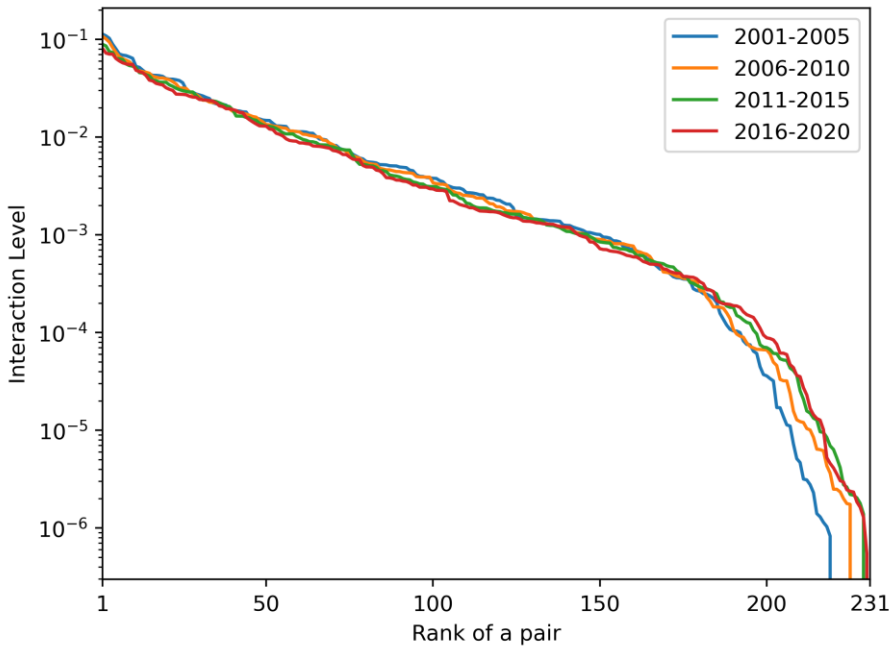

Figure 1: Distributions of paired interaction between divisions

Figure 2 shows the dynamic of interaction of the most tied divisions. For each five-year period 5 pairs of divisions with the greatest Jaccard index are selected. For the first three periods, we observe the same leaders of divisions' pairs:

20 Language, Communication and Culture & *21 History and Archaeology*;
01 Mathematical Sciences & *02 Physical Sciences;*
19 Studies in Creative Arts and Writing & *20 Language, Communication and Culture*;
02 Physical Sciences & *09 Engineering*;
21 History and Archaeology & *22 Philosophy and Religious Studies*.

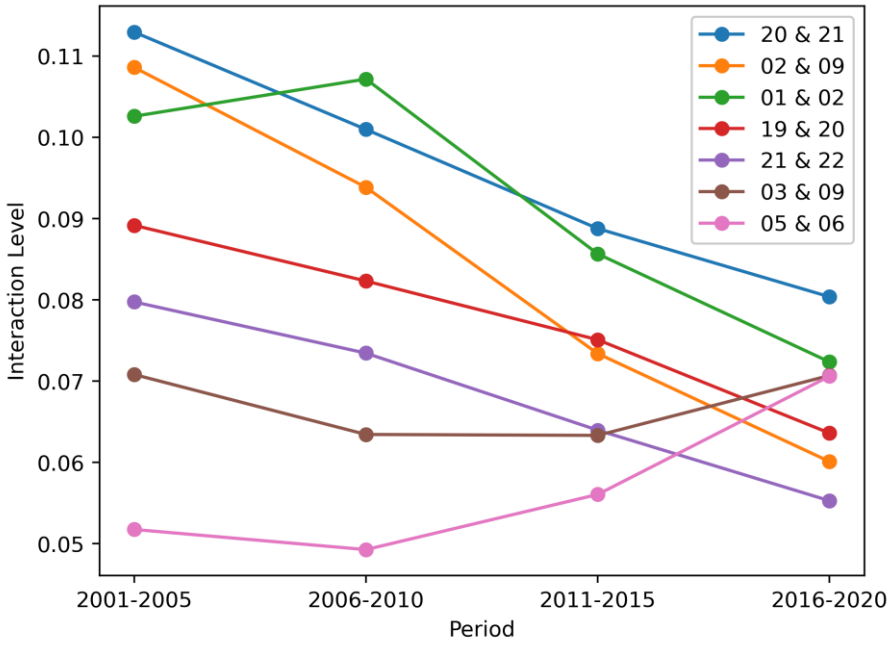

Figure 2: Dynamics of seven leaders among research divisions

Two last pairs of the leaders moved down to the 6-th and 10-th positions respectively in the last period. The following pairs replaced them: *03 Chemical Sciences* & *09 Engineering*, and *05 Environmental Sciences* & *06 Biological Sciences*. Among seven leaders the following pair *02 Physical Sciences* & *09 Engineering* has the highest decrease in interaction. Its Jaccard index dropped from 0.1085 in 2001–2005 to 0.0600 in 2016–2020. The data for the last 2 years shows that the decrease has stopped – Jaccard index increased by a tiny value from 0.0595 in 2019 to 0.0560 in 2020. Among leaders, the highest increasing in interaction is demonstrated by pair *05 Environmental Sciences* & *06 Biological Sciences*. It moved down from the position #12 in the first period to position #4 in the last period. The data for the last 2 years shows that interaction between divisions *05* and *06* continues to grow with 4.8% per year rate.

Figure 3 shows dynamic for the most changeable pairs of research divisions. We considered only pairs that at least in one of the periods has fallen into a quartile with the greatest values of Jaccard index. Within these pairs, we chose the 6 most dynamic; the one that has their Jaccard index changed the most in terms of increasing and decreasing between the first (2001-2005) and last (2016-2020) periods. Among chosen pairs the most rapid decrease in interaction happened for divisions *14 Economics* & *22 Philosophy and Religious Studies* – it has dropped from 0.031 in 2001-2005 to 0.0121 in 2016-2020. The data for the last 2 years shows that it continues to decrease with 9.4% per year rate. In 2020, Jaccard index for divisions *14* & *22* takes a value of 0.0096. For all time of observations, the highest increase in interaction happens for divisions *03 Chemical Sciences* & *10 Technology* – from 0.0073 in 2001-2005 to 0.0241 in 2016-2020. However, in the last five-year period the increase has stopped. The data for the last 2 years shows that decrease is present with a rate of -9% per year. In 2020, Jaccard index for divisions *03 Chemical Sciences* & *10 Technology* takes value of 0.0203. For the last 2 years, interaction between divisions *03 Chemical Sciences* & *05 Environmental Sciences* has

increased drastically (24%). In 2020 Jaccard index for divisions *03 Chemical Sciences* & *05 Environmental Sciences* takes a value of 0.024.

In addition to paired interaction, we analyzed the cumulative interaction of divisions. For this stickiness index [5] is used. Stickiness index $G(A)$ of division A is a sum of all Jaccard indexes between A and other divisions as follows:

$$G(A) = \sum_{p:\, p \in \mathbf{F},\, p \neq A} S(A, p),$$

where **F** denotes a set of research divisions.

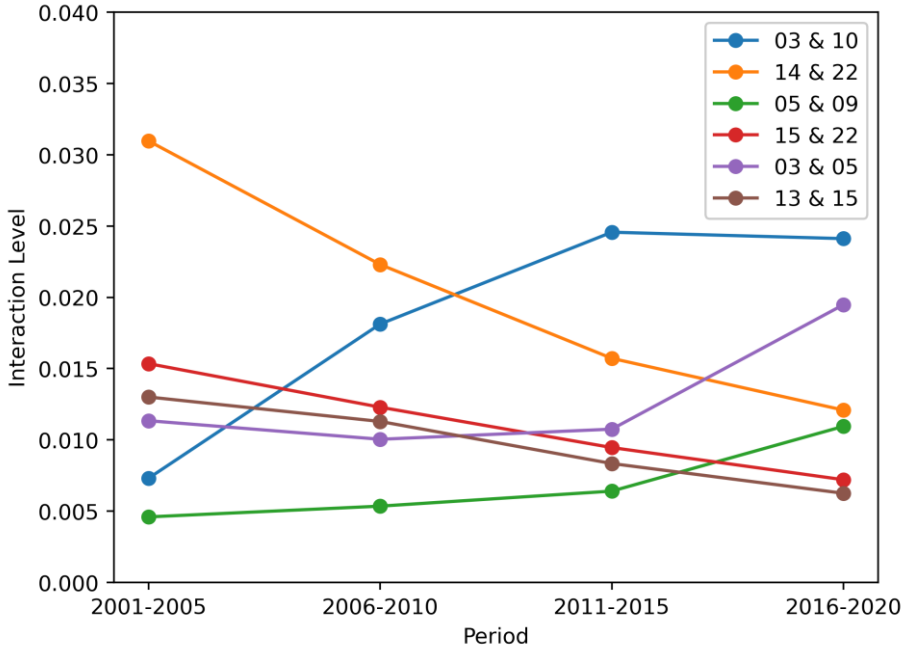

Figure 3: Dynamics for the most changeable research divisions between the first and last periods

Using stickiness indexes let's find research divisions with the highest level of interaction. The distributions of stickiness indexes for each of the periods are shown in Figure 4. The leaders by stickiness index are *09 Engineering* and *16 Studies in Human Society* for the all 4 periods.

Figure 4 shows that all research divisions tend to have their stickiness decreased over time. This conclusion is confirmed by Gini index for stickiness distributions that decreases from 0.197 in the first period to 0.188 in the last period. For all time of observations, the most rapid decrease in stickiness index is demonstrated by the following research divisions:

22 Philosophy and Religious Studies – -34%;
02 Physical Sciences – -31%;
19 Studies in Creative Arts and Writing – -30%;
01 Mathematical Sciences – -26%;
12 Economics – -25%.

4. Interaction between research groups

In addition to research divisions based on Dimensions data we can retrieve a number of papers assigned with each research group. At the same time, we can get a number of above-mentioned papers that were assigned to several research groups simultaneously. By using this data, we can assess the level of interaction between two research groups in the same way as for divisions. For example, there are 80115 papers assigned to group *0806 Information Systems* in 2019, and 2934 of them also belong to group *1503 Business and Management*. Group *1503* consist of 59662 papers published in 2019.

Hence, the quantitative assessment of interactive between *0806 Information Systems* and *1503 Business and Management* is $S(0806, 1503) = \frac{2934}{80115 + 59662 - 2934} = 0.021$.

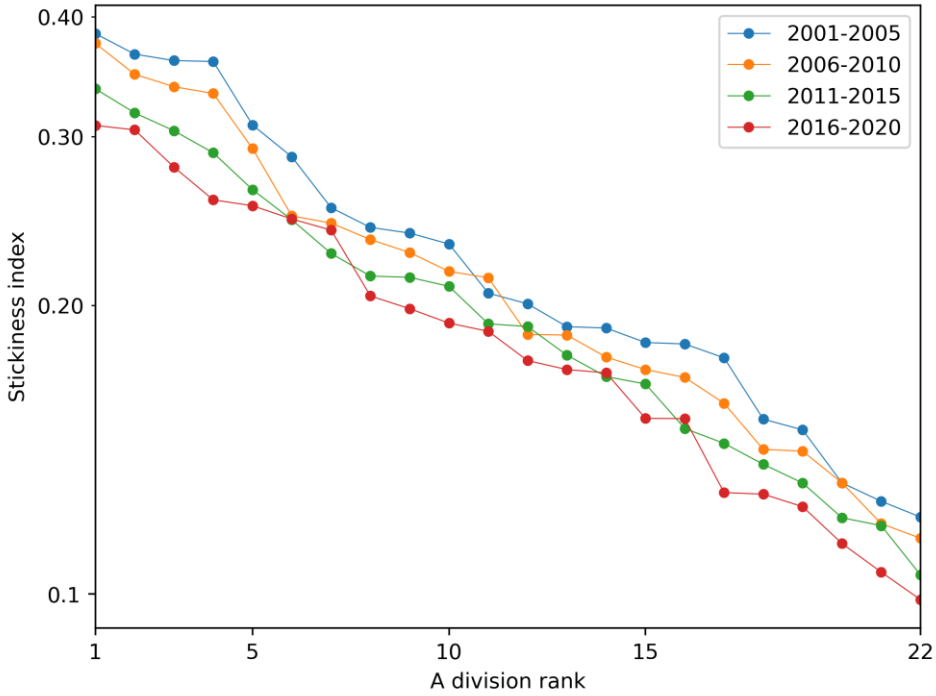

Figure 4: Divisions' stickiness indexes distribution

Figure 5 shows the Jaccard index distributions for pairs of research groups with different divisions within the four of the five-year periods. We empirically set a threshold for a number of papers for a research division to be 1000, so that research divisions with less than 1000 papers are not considered. In total 145 research groups are considered, hence the interactive level of 10440 pairs of the research groups for each five-year period were calculated. Most of the research groups have zero Jaccard index. Figure 4 shows the same results as with the research divisions' interactions. But now the pairs at the end of the distribution have their interactions increased by a larger factor which shows that as the time goes on interdisciplinarity between research divisions increases. This can be seen by looking at Figure 5 and observing that the first period 2001-2005 has 334 pairs of research divisions with Jaccard index greater than zero. The last period has 551 pairs, which give an increase of 217 pairs over the last 2 decades. The same effect shows Gini coefficient that decreases in time in the following way:

$Gini_G(2001 \div 2005) = 0.983$; $Gini_G(2006 \div 2010) = 0.98$;

$Gini_G(2011 \div 2015) = 0.978$; $Gini_G(2016 \div 2020) = 0.975$.

Figure 6 shows the dynamic of the interaction for the most tied groups. We apply the same selection here as for the divisions. For the all four periods, we observe the following 3 leaders that always stay in the top 5:

1205 Urban and Regional Planning & 1507 Transportation and Freight Services;

1903 Journalism and Professional Writing & 2001 Communication and Media Studies;

1902 Film, Television and Digital Media & 2001 Communication and Media Studies.

Some of the leaders increase interaction as time goes on, some decrease interaction, some switch between increasing and decreasing interaction. A trend towards increasing interaction shows *0502 Environmental Science and Management & 0602 Ecology*. This pair increases the interaction from 0.11 in the first period to 0.16 in the last period. A trend towards decreasing interaction show a few pairs of groups: *1205 Urban and Regional Planning & 1507 Transportation and Freight Services, 1903 Journalism and Professional Writing & 2001 Communication and Media Studies*, and *0702 An-*

imal Production & 0908 Food Sciences. They decrease interaction for the first 3 periods but have a slight increase for the last period. Hence, no leader changed its interactive level significantly.

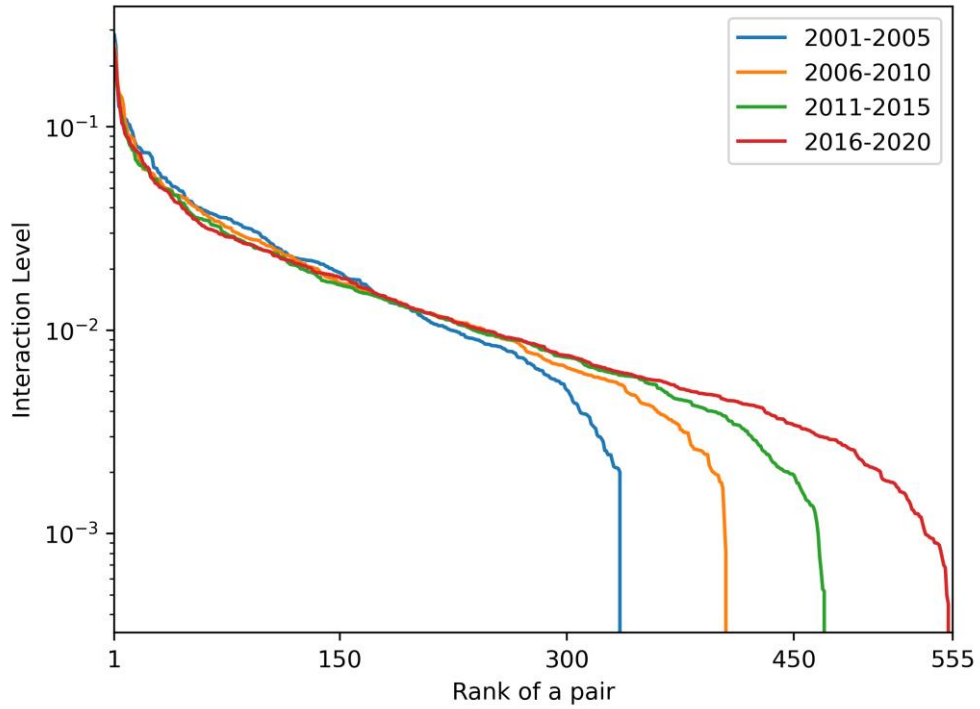

Figure 5: Distributions of paired interaction between groups

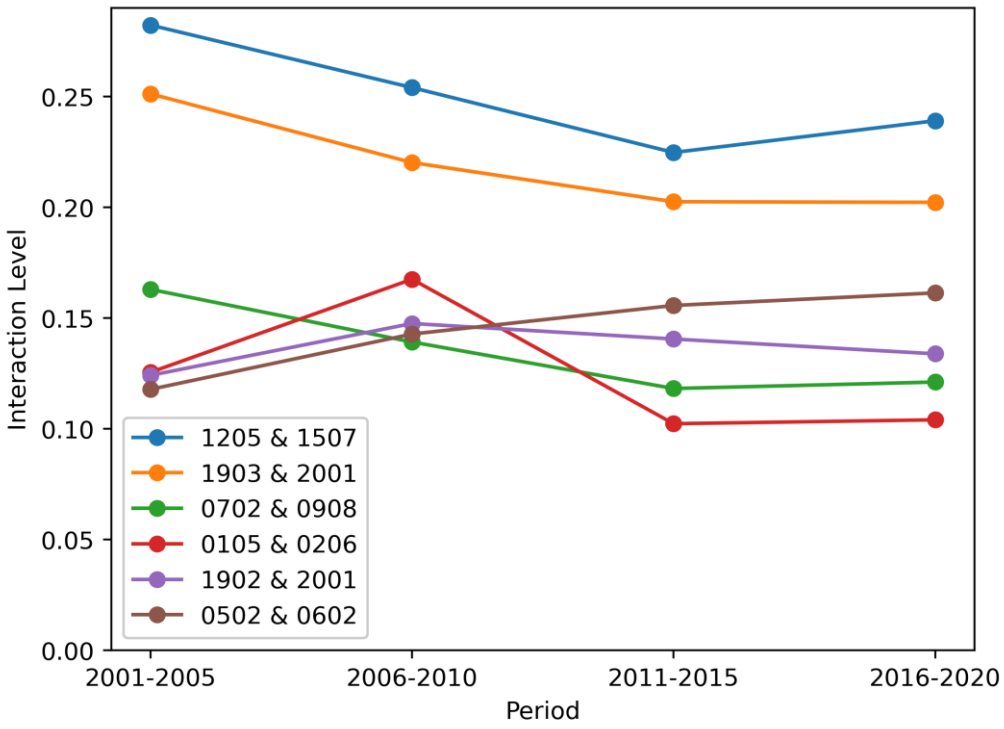

Figure 6: Dynamics of six leaders among research groups

Figure 7 shows dynamic for the most changeable research groups. We use the same approach as with the research divisions' selection. Overall we analyzed the 6 most changeable research groups:

0399 Other Chemical Sciences & 0699 Other Biological Sciences;

0206 Quantum Physics & 0906 Electrical and Electronic Engineering;

0601 Biochemistry and Cell Biology & 1112 Oncology and Carcinogenesis;

0401 Atmospheric Sciences & *0912 Materials Engineering*;

0202 Atomic, Molecular, Nuclear, Particle and Plasma Physics & *0307 Theoretical and Computational Chemistry*;

0401 Atmospheric Sciences & *0901 Aerospace Engineering.*

Among chosen pairs the most rapid increase in interaction happened for groups *0399 Other Chemical Sciences* & *0699 Other Biological Sciences* – it has increased at 378% from 0.02113 in 2001-2005 to 0.10121 in 2016-2020. In 2020 Jaccard index for this pair equals 0.1411. But, the year pace fell, and became 9.1% for 2019–2020. The pair *0206 Quantum Physics* & *0906 Electrical and Electronic Engineering* has increased interaction at 288% from 0.00634 to 0.02464. In 2020 Jaccard index for this pair equals 0.0258. But, the year pace fell, and became 7.1% for 2019–2020. The pair *0601 Biochemistry and Cell Biology* & *1112 Oncology and Carcinogenesis* has increased interaction from 0.00630 to 0.01869. The most rapid decrease in interactions is observed for the pair *0401 Atmospheric Sciences* & *0912 Materials Engineering* with moving from 0.00834 to 0.00125 (about 84%). The pairs *0202 Atomic, Molecular, Nuclear, Particle and Plasma Physics* & *0307 Theoretical and Computational Chemistry* and *0401 Atmospheric Sciences* & *0901 Aerospace Engineering* show approximately the same decrease in interaction at about 80%.

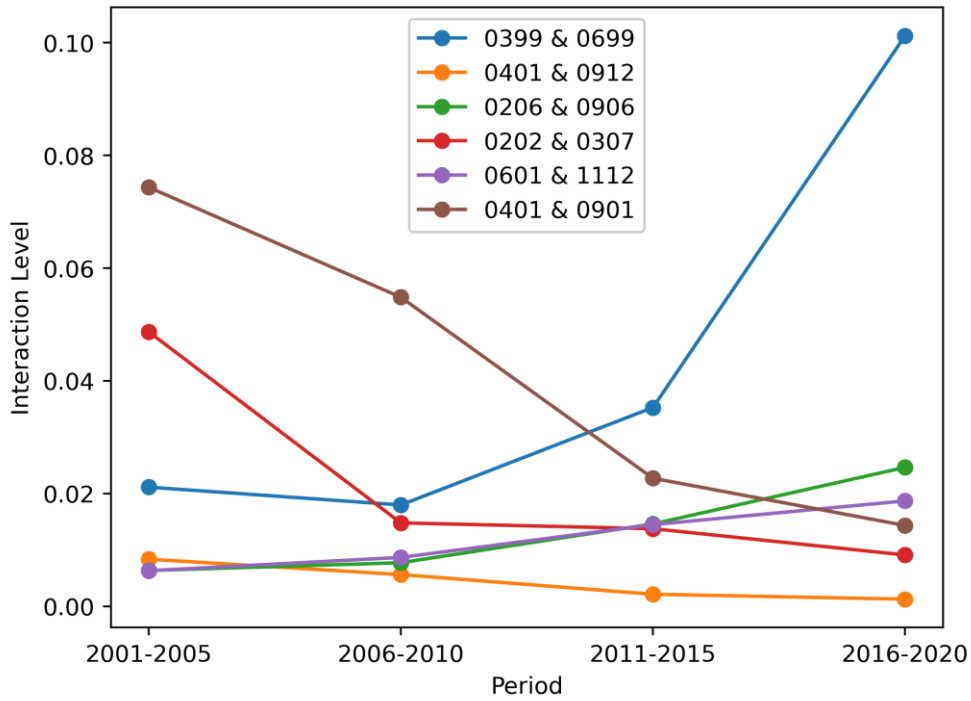

Figure 7: Dynamics for the most changeable research groups between the first and last periods

We also observed that many pairs of research groups have moved from zero interaction to greater than zero and vice versa. According to our calculations 235 pairs of research groups has exceeded zero interaction and only 18 pairs has reached zero interaction when comparing the first (2001-2005) and last (2016-2020) periods. It conforms to earlier evidence about the increase of interdisciplinarity on the low level.

As well as with research divisions, we analyzed the cumulative interaction of groups. We used the same formula of stickiness index but, naturally, applied to Jaccard indexes of research groups. The distributions of stickiness indexes for each of the periods are shown in Figure 8. The leaders by stickiness index are:

0502 Environmental Science and Management;

2001 Communication and Media Studies;

1205 Urban and Regional Planning.

Figure 8 confirms to the previous conclusion regarding to divisions and shows that with time research groups tend to have a more equally distributed stickiness index. It is also observed from the

number of research groups that increased their stickiness index from zero to greater than zero. 11 research groups have increased their stickiness index from zero in the first period to positive number in the last period, and only one research group has decreased it to zero. The same effect shows Gini index for the stickiness index that decreases from 0.4722 in the first period to 0.4519 in the last period. For all time of observations, the most rapid decrease in stickiness index took place for the following research groups:

1603 Demography – -92%;
1301 Education Systems – -83%;
0901 Aerospace Engineering – -71%;
0307 Theoretical and Computational Chemistry – -59%;
1101 Medical Biochemistry and Metabolomics – -59%.

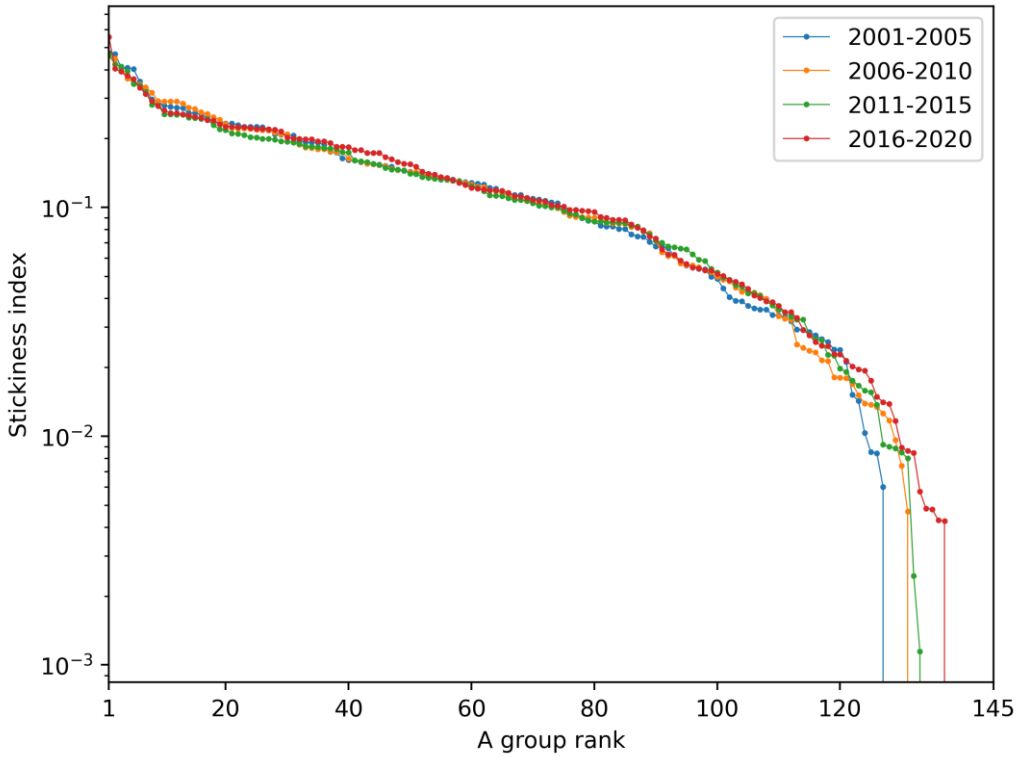

Figure 8: Groups' stickiness indexes distribution

5. Application for improvement of ANZSRC

ANZSRC as any hierarchical classifying system tries to combine the similar objects in the same cluster and makes any two clusters dissimilar. Hence, a research group has to be more similar, has to have higher interaction with the research groups inside its division, than with the research groups from any other division. To formalize this thesis regarding to research group G_{11} from division D_1 we introduce the following:

1) G_{12} and G_{13} denote research groups with highest interaction with G_{11} inside division D_1, and besides $J(G_{11}, G_{12}) > J(G_{11}, G_{13})$;

2) G_{22} and G_{23} denote research groups from division D_2, which are most tied with the research group G_{11} from division D_1, and besides $J(G_{11}, G_{22}) > J(G_{11}, G_{23})$.

Assumption: research group G_{11} is assigned suspiciously to division D_1, if $J(G_{11}, G_{12}) < J(G_{11}, G_{22})$ AND $J(G_{11}, G_{13}) < J(G_{11}, G_{23})$. In this case, division D_2 is more suitable for research group G_{11}, than division D_1. Hence, ANZSRC may be improving its classifying system by moving research group G_{11} from division D_1 to division D_2.

We checked all the research groups on base of their Jaccard index for 2016-2020 data and found 5 problem research groups according to proposed Assumption (Table 1). For reliability reason only research groups with $J(G_{11}, G_{23}) > 0.05$ are considered.

According to Table 1 the following changes in ANZSRC are proposed:

1) move *2001 Communication and Media Studies* from *20 Language, Communication and Culture* to *19 Studies in Creative Arts and Writing;*

2) move *0909 Geomatic Engineering* from *09 Engineering to 04 Earth Sciences*;

3) move *1502 Banking, Finance and Investment* from *15 Commerce, Management, Tourism and Services* to *14 Economics;*

4) move *0105 Mathematical Physics* from *01 Mathematical Sciences* to *02 Physical Sciences*;

5) move *0602 Ecology* from *06 Biological Sciences* to *05 Environmental Sciences*.

Table 1

Problem research groups in ANZRSC

Problem Group	Most tied groups inside the division	Jacard index	Most tied groups inside concurrent division	Jacard index
2001 Communication and Media Studies	*2002 Cultural Studies*	0.0379	*1903 Journalism and Professional Writing*	0.2022
	2004 Linguistics	0.0076	*1902 Film, Television and Digital Media*	0.1338
0909 Geomatic Engineering	*0901 Aerospace Engineering*	0.0110	*0406 Physical Geography and Environmental Geoscience*	0.0855
	0906 Electrical and Electronic Engineering	0.0108	*0404 Geophysics*	0.0527
1502 Banking, Finance and Investment	*1503 Business and Management*	0.0304	*11403 Econometrics*	0.0503
	1507 Transportation and Freight Services	0.0000	*1402 Applied Economics*	0.0502
0105 Mathematical Physics	*0102 Applied Mathematics*	0.0386	*0206 Quantum Physics*	0.1040
	0101 Pure Mathematics	0.0143	*0203 Classical Physics*	0.0515
0602 Ecology	*0603 Evolutionary Biology*	0.0599	*0502 Environmental Science and Management*	0.1613
	0607 Plant Biology	0.0522	*0501 Ecological Applications*	0.0655

6. Conclusions

We analyzed the interaction of research divisions and research groups for 4 five-year periods. The level of interactions is assessed by Jaccard index. We analyzed paired and cumulative interaction for both research divisions and research groups. Only research groups of different research divisions were considered. Paired interaction allowed to find pairs that interact the most and analyze the behavior of different interactions over time.

Using paired interaction we analyzed leaders and the most changeable research divisions and groups in terms of interaction. Paired interaction for research divisions shows that every consecutive five-year period has decreased irregularity of its distribution of interaction. This also confirms the Gini index and the number of pairs with non-zero interaction. Cumulative interaction shows that all research divisions tend to have their stickiness decreased over time. The same effect shows Gini index

for the stickiness index that decreases from 0.197 in the first period (2001-2005) to 0.188 in the last period (2016-2020).

Paired interaction for research groups showed the same results but difference between two consecutive periods is greater by a larger factor. Cumulative interaction for research groups showed that with time research groups tend to have a more equally distributed stickiness index. It is also observed from the number of research groups that increased their stickiness index from zero to greater than zero and Gini index.

On base of interacting assessments during 2016-2020 we identified 5 research groups that have been assigned suspiciously to divisions in ANZSRC. They are as follows: *0105 Mathematical Physics, 0602 Ecology, 0909 Geomatic Engineering, 1502 Banking, Finance and Investment* and *2001 Communication and Media Studies.* All the mentioned research groups have at least a pair of more similar research groups in concurrent divisions with statistically significant level. Those 5 research groups also have strong semantic ties with concurrent divisions, this can be an argument for adapting of ANZSRC.

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