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A comparison of Australian and European Union research performance profiles

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The views expressed in this paper do not reflect the official position of the Australian Government, the European Commission, or The Australian National University.

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Introduction

Governments worldwide face the challenge of how best to prioritise their international science and innovation (S&I) cooperation activities. This involves balancing the intrinsic benefits that may arise from international S&I cooperation with extrinsic considerations – diplomacy, trade, national security etc.

The interplay of these intrinsic and extrinsic considerations means that complex and often ambiguous tradeoffs need to be addressed by policymakers. In some cases international S&I cooperation priorities will reflect extrinsic diplomatic and geopolitical goals. In other cases the objectives will relate more closely to balancing the costs, risks and benefits of particular bilateral and multilateral S&I cooperation opportunities.

Given the limited financial resources available to support international S&I cooperation it is useful for policymakers to have access to appropriate decision-support tools and information. This should help to avoid wasteful resource allocations caused by a lack of access to relevant information.

This paper seeks to contribute to the evolving policy framework in this area by considering ways of characterising and mapping international imbalances in research performance.

The focus is upon bilateral imbalances in research performance, as expressed in relative citation performance for journal articles indexed by Thomson-Reuters publications and citations datasets (formerly known as the Institute for Scientific Information, or ISI).

To this end the paper:

- proposes a simple policy-oriented framework for understanding the potential pay-offs and risks associated with international S&I cooperation; and
- provides an illustration of the application of this framework by populating it with bibliometric data on bilateral imbalances in S&I capability as measured by Relative Citation Impact.

An extensive Technical Annex is available upon request (*info@feast.org*) containing detailed data on a research field by research field basis.

Characterising imbalances in bilateral S&I capability

One way of thinking about international S&I cooperation is to frame the costs, risks and benefits in terms of a 'pay-off' matrix. The basic form of such a matrix is presented in Figure 1 below.

This framework distinguishes between four types of bilateral S&I cooperation scenario:

- *forge ahead opportunities* – a situation in which both parties are currently strong performers (RCI's above 1.0);
- *pull-up opportunity and pull-down risk* – two situations in which one party is a strong performer and one party is a weak performer; and
- *catch-up opportunities* – a situation in which both parties are weak performers.

It is important to stress that there is a strong rationale for bilateral collaboration in each of these four quadrants. The framework is therefore able to inform the bilateral element of international collaboration strategies.

When *forge-ahead* opportunities exist both parties stand to gain by exploiting economies of scale and scope in these research fields together with other synergies between distinctive capabilities (such as research infrastructure assets). In such circumstances the potential benefits will tend to be fairly symmetrical, and as a result relatively unproblematic compared to the other scenarios.

When a mix of *pull-up opportunities* & *pull-down risks* exist the situation is more asymmetric and potentially problematic. One party may stand to gain more than the other party. In this case it is important to be clear as to why the cooperation is prioritised, particularly in relation to other 'collateral benefits' in the diplomatic and trade domains.

	Country Y Capability Index > 1.0	**Country Y Capability Index < 1.0**
Country X Capability Index > 1.0	X: Forge-ahead opportunity Y: Forge-ahead opportunity	X: Pull-down risk Y: Pull-up opportunity
Country X Capability Index < 1.0	X: Pull-up opportunity Y: Pull-down risk	X: Catch-up opportunity Y: Catch-up opportunity

Figure 1: Bilateral cooperation pay-off matrix

When *catch-up opportunities* are present both parties stand to gain from cooperation for similar reasons as in the *forge-ahead* case. In such situations there can be much to be gained from pooling resources, capabilities and research infrastructures – generating greater scale and scope in the research effort to mutual advantage.

By intent, this framework greatly simplifies international collaboration rationales. Precisely because international collaboration is a complex and multi-faceted issue, it is useful to provide a relatively simple framework that can then be built upon by adding additional levels of complexity.

There are a range of implicit assumptions sitting behind this sort of conceptualisation. One such assumption is that researchers view potential collaborative relationships in a similar manner to the policy community. In reality, the way in which inter-personal relationships stimulate and mediate collaboration matters greatly. In particular, the 'relational capital' built-up over time is a key risk-reduction mechanism and will, therefore, naturally tend to drive international collaboration patterns. Given the risks faced, this aspect of the collaboration landscape will be as important, if not more important, than imbalances and convergences in demonstrated science and innovation capability. This dimension can be added to the current framework in future work.

Given the potential importance to governments of knowing in which quadrant a nation sits in regard to different bilateral S&I cooperation partners it is useful to consider how best to operationalise this framework. It is also useful to consider possible implications for multilateral S&I cooperation.

When operationalising this framework it is useful to make borderline revealed capabilities explicit by introducing a grey area between the different capability areas – resulting in a 3×3 rather than a 2×2 matrix.

One way of implementing the framework is to consider the *Relative Citatation Impact* (RCI) metric. RCI refers refers to the ratio of average citations per paper for a county in a given research field (or thematic area) divided by the average citations per paper in that research field or thematic area globally. A RCI ratio greater than 1.0 indicates higher than world average performance. An RCI ratio below 1.0 indicates lower than world average performance.

It is important to stress that RCI is just one measure of capability imbalances. This framework can be used to organise data using any suitable measure or suite of measures. In principle, the framework can also be applied

	EU-27 strengths RCI > 1.1	**EU-27 borderline RCI 0.9-1.1**	**EU-27 weaknesses RCI < 0.9**
Australian strengths RCI > 1.1	Geocsciences Physics Plant & Animal Science	Clinical Medicine Ecology/Environment Education Mathematics Space Science	
Australian borderline RCI 0.9-1.1	Agricultural Sciences	Biology & Biochemistry Chemistry Computer Science Engineering Immunology Materials Science Microbiology Molecular Biology & Genetics Multidisciplinary Science Neurosciences & Behaviour Pharmacology Physchology/Psychiatry Social Sciences, general	
Australian weaknesses RCI < 0.9			Economics & Business Law

Figure 2: S&I Cooperation pay-off matrix at the 24 research field level

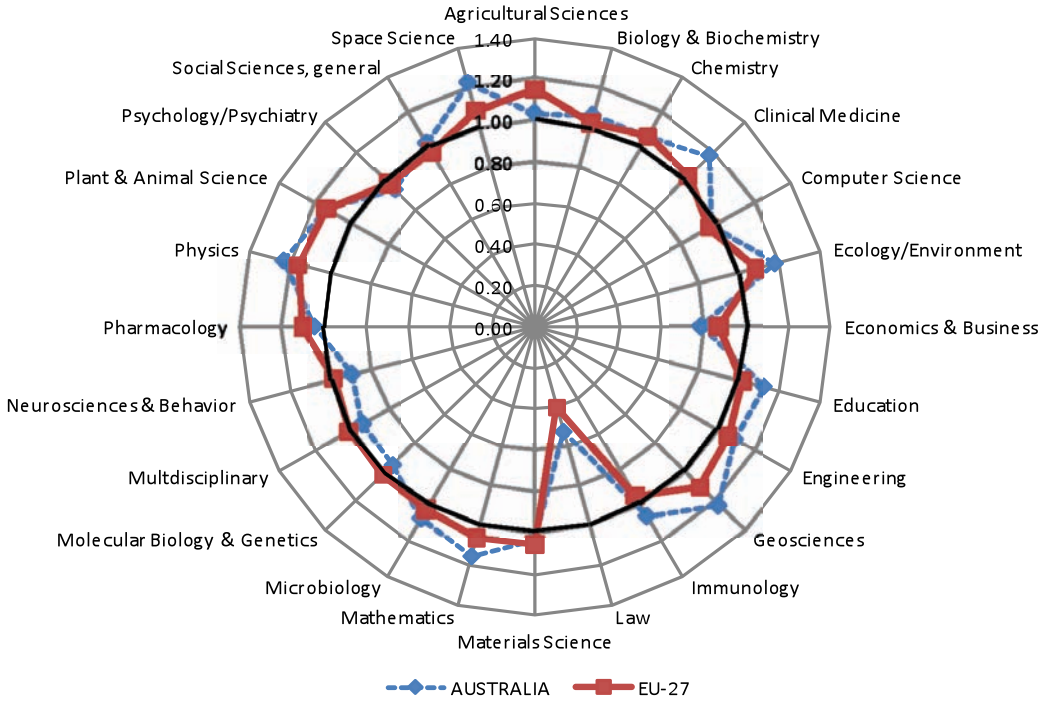

Figure 3: Radial diagram showing the RCI performance of Australia versus the EU-27
Source: THOMSON REUTERS® National Science Indicators®

to the technology development and innovation domains using appropriate metrics.

Operationalising the cooperation pay-off framework

The framework has been applied using Thomson-Reuters' *National Science Indicators* (NSI) data acquired by the Australian Government Department of Innovation, Industry, Science and Research (DIISR) and made available to the Forum for European-Australian Science and Technology cooperation (FEAST).

NSI data at both a high level of aggregation and the more detailed 'deluxe' level were used – covering the period 2003-2007. The standard NSI data provides a picture based upon 24 research field classes whereas the deluxe data provides data at a far more detailed 106 category level.

Both levels of aggregation are useful for policy and strategy purposes: the broad picture helps to frame basic comparisons by field and nation whilst the more detailed data helps to address more specific issues of greater relevance to researchers, program structures and funding alternatives.

National coverage was extended to the following:

- EU-27 in aggregate;
- all individual EU Member States;
- Canada;
- China;
- India;
- New Zealand;
- South Africa; and
- USA.

This is a highly selective set of nations in order to avoid over-complicating the presentation of the core framework used in this paper. A subsequent paper will discuss the performance over time of a wider set of countries.

In order to avoid placing unwarranted weight on RCI's based on small numbers of publications countries with less than 100 publications in a given field of research (ie. 20 per year over the five years) were excluded from the analysis.

It is also important to note that these results may not give an accurate picture of revealed comparative advantage for information and communication technologies (ICT) because journal articles per se are recognised to have limited relevance in that field. Follow-up work on operationalising this framework for ICT, and other engineering-related research fields in which journal citation performance has limited relevance, will be based upon refereed conference proceedings.

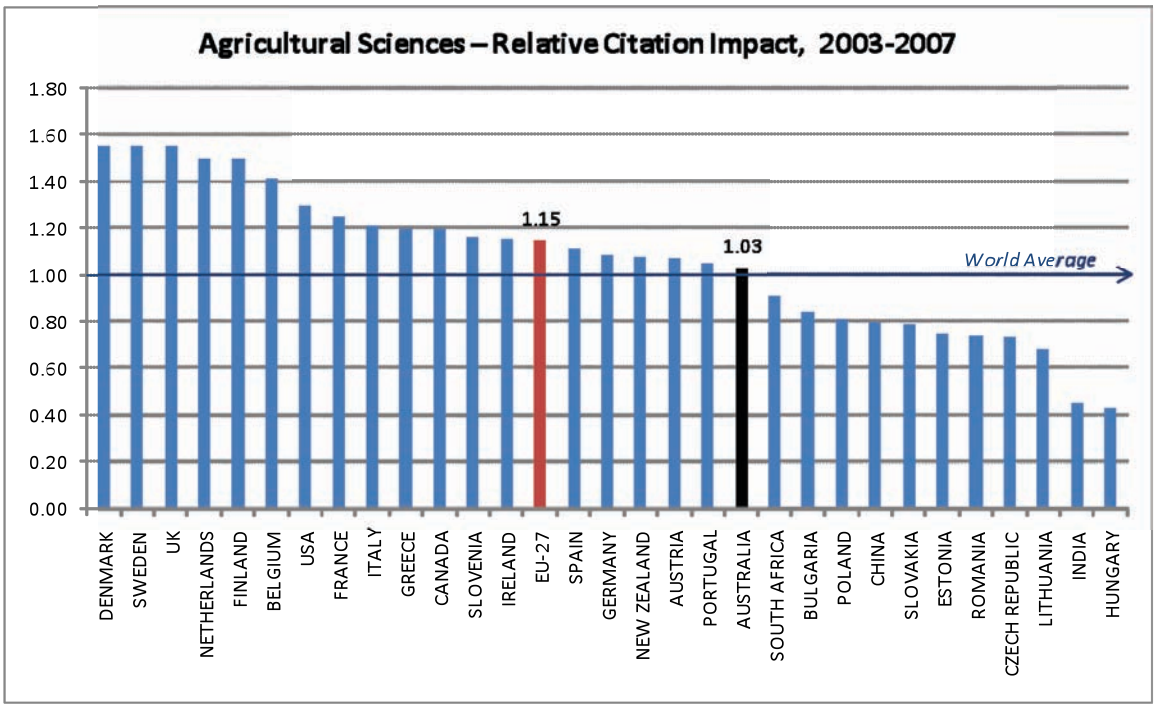

Figure 4: RCI ranking for Agricultural Sciences

Source: THOMSON REUTERS® National Science Indicators®

	Australia	EU-27	Canada	China	France	Germany	India	New Zealand	South Africa	UK	USA
Agricultural Chemistry	0.96	1.10	1.14	0.74	0.99	1.29	0.78	0.91	0.84	1.37	1.25
Agriculture/Agronomy	1.50	1.25	1.38	1.01	1.41	1.39	0.46	1.15	0.90	1.67	1.24
Food Science/Nutrition	1.02	1.09	1.14	0.67	1.25	0.87	0.44	1.27	0.91	1.60	1.42
Agricultural Sciences	**1.03**	**1.15**	**1.20**	**0.80**	**1.25**	**1.09**	**0.45**	**1.08**	**0.91**	**1.56**	**1.30**

Figure 5: RCI ranking for Agricultural Sciences subfields

Source: THOMSON REUTERS® National Science Indicators®

A final caveat to the results that follow is that, as the first Discussion Paper in this series indicated[1], apparent national performance is significantly influenced by patterns of multilateral research collaboration. These multilateral collaboration clusters can themselves be 'assets' with as strong an impact on citation performance as the national location of researchers.

The resulting picture therefore provides a useful profile of how both the EU and Australia's research competitiveness stacks-up against many of key partners.

Findings

The above table, Figure 2, summarises the results obtained using the NSI data at the higher level of aggregation. The table profiles the overall bilateral state-of-play for Australia vis-à-vis the EU-27 in aggregate.

As subsequent results show, there is great variation within the EU-27 and consequently this aggregate EU-27 based view can be misleading. It is therefore important to recognise that specific bilateral cooperation pay-offs exist between Australia and different EU Member States.

Borderline cases with an RCI of greater than 0.9 and less than 1.1 are identified in the grey central row and column.

The picture that emerges for the Australia-EU-27 relationship is that most research fields lie in the borderline areas with an RCI of between 0.9 and 1.1, but with a significant number of fields in which Australia has

[1] Matthews *et al* (2009). *A Bibliometric Analysis of Australia's International Research Collaboration in Science, Engineering and Technology: Analytical Methods and Initial Findings*. Forum for European-Australian Science and Technology cooperation. FEAST Discussion Paper 1/09.
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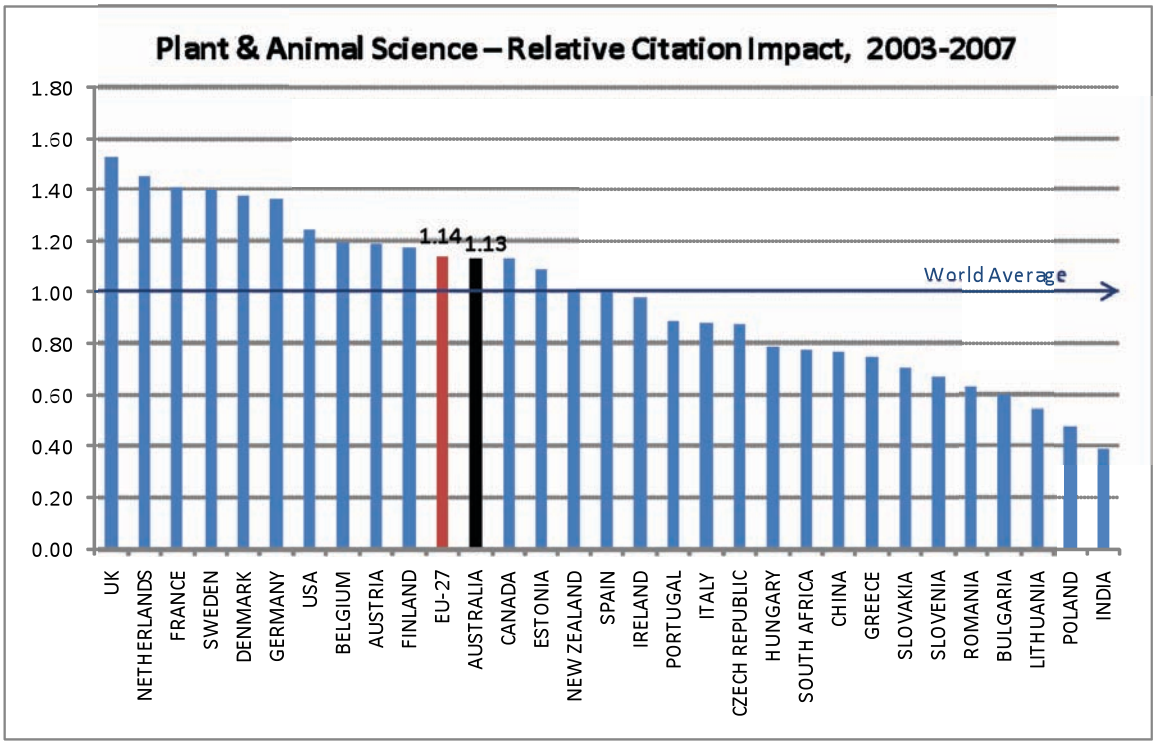

Figure 6: RCI ranking for Plant & Animal Sciences

Source: THOMSON REUTERS® National Science Indicators®

	Australia	EU-27	Canada	China	France	Germany	India	New Zealand	South Africa	UK	USA
Animal & Plant Sciences	1.13	1.09	0.92	0.70	1.16	1.26	0.45	0.96	0.57	1.35	1.19
Animal Sciences	1.18	1.13	1.38	0.62	1.31	1.17	0.25	1.09	0.90	1.54	1.27
Aquatic Sciences	1.14	1.14	1.25	0.75	1.22	1.34	0.50	1.06	1.02	1.34	1.16
Entomology/Pest Control	1.14	1.18	1.00	0.63	1.36	1.31	0.58	1.06	0.92	1.52	1.17
Plant Sciences	1.11	1.17	0.89	0.67	1.45	1.51	0.52	0.87	0.62	1.80	1.32
Veterinary Med/Animal Health	1.05	1.03	1.33	1.27	1.43	0.77	0.22	1.33	0.83	1.49	1.32
Plant & Animal Science	**1.13**	**1.14**	**1.13**	**0.77**	**1.41**	**1.36**	**0.39**	**1.02**	**0.78**	**1.53**	**1.25**

Figure 7: RCI ranking for Plant & Animal Science Subfields

Source: THOMSON REUTERS® National Science Indicators®

clear strengths and the EU-27 exhibit borderline performance.

There are three fields: geosciences, physics and plant & animal sciences in the *forge-ahead* quadrant where there are mutual advantages to cooperation based upon further exploiting existing clear strengths.

There are two research fields (economics & business and law) in which both the EU-27 and Australia exhibit clear weaknesses.

One point to note is that the choice of dataset does have an impact on the results obtained. RCI data are also available on-line via Thomson-Reuter's *Web-of-Science* service. These data cover a longer time period (1999-2009) and do not allow the user to select a shorter time period. Not surprisingly, research fields in which RCI performance has been changing will perform differently according to whether a 2003-2007 or 1999-2009 timeframe is used.

Another useful perspective on relative research performance is provided in the radial diagram (see Figure 3) of Australian versus EU-27 RCI performance. The continuous line indicates EU-27 performance and the dotted line Australian performance. The greater the distance from the centre of the diagram the higher the RCI performance.

In general terms the two profiles are fairly similar, with comparable strengths in Physics, Ecology/Environment, Education, Engineering, Geosciences, and Mathematics. Both parties also exhibit apparent weaknesses in Law,

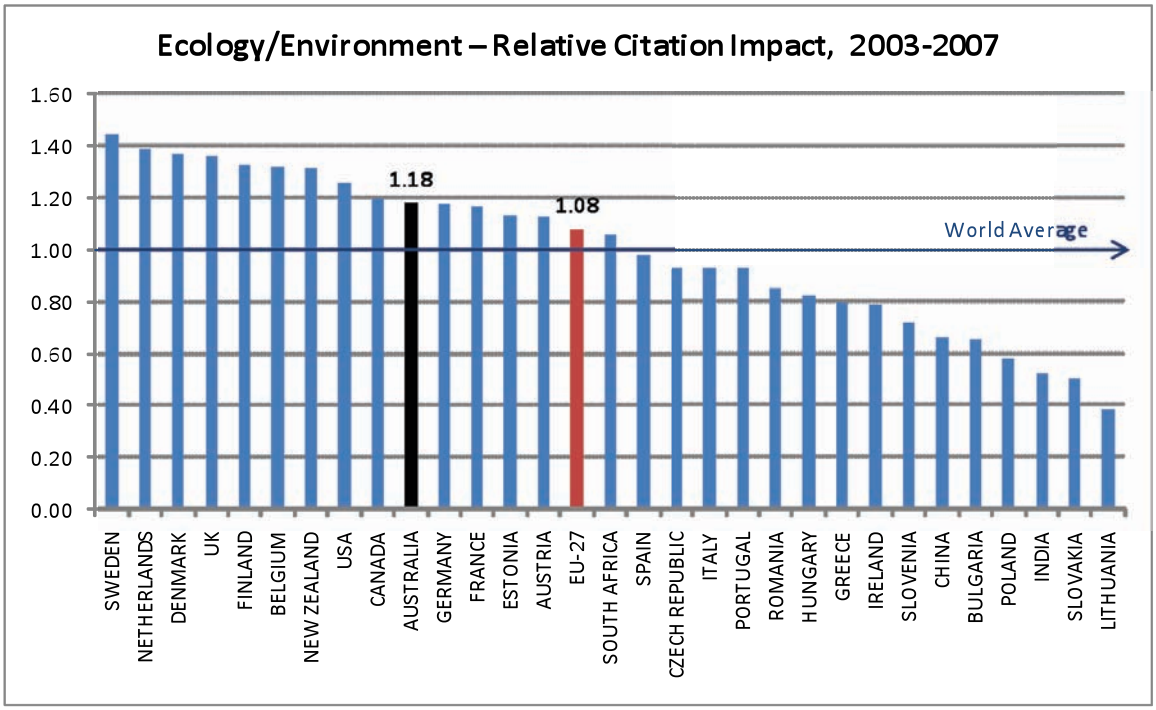

Figure 8: RCI ranking for Ecology/Environment

Source: THOMSON REUTERS® National Science Indicators®

	Australia	EU-27	Canada	China	France	Germany	India	New Zealand	South Africa	UK	USA
Environment/Ecology	1.18	1.08	1.19	0.66	1.17	1.18	0.52	1.32	1.06	1.36	1.26
Ecology/Environment	**1.18**	**1.08**	**1.19**	**0.66**	**1.17**	**1.18**	**0.52**	**1.32**	**1.06**	**1.36**	**1.26**

Figure 9: RCI ranking for Ecology/Environment

Source: THOMSON REUTERS® National Science Indicators®

however that field has unusual characteristics as it is not well handled at present by the journals indexed by Thomson-Reuters.

We now turn to considering some selected research fields. These are:

- Agricultural Sciences;
- Plant & Animal Science;
- Ecology/Environment.

These fields of research have been chosen because they are topical and are areas in which it is often assumed that Australia has particular strengths.

In each case, we present a graph of national performance ranked by RCI. This allows the relative performance of Australia versus the EU-27 in aggregate to be grasped as well as more detailed bilateral comparisons between Australia and different EU Member States together with the selected comparator nations. Full details for all research fields at both levels of data aggregation can be found in the Technical Annex.[2] The following comments and observations will assist the reader in interpreting the results contained in that annex.

In Agricultural Sciences the EU-27 performs more strongly than Australia because the average EU performance is pulled up by the Scandinavian nations together with the UK and Belgium (all of which perform better than the USA). This can be seen clearly in Figure 4.

Figure 5 contains a more detailed breakdown for Agricultural Sciences. This reveals that Australia is strongest in Agriculture/Agronomy (with an RCI of 1.5 and second only to the UK amongst these nations) but more marginal in Agricultural Chemistry and in Food Science/Nutrition.

[2] To request a copy of the Technical Annex send an email to *info@feast.org*.

As regards Plant & Animal Science, aggregate EU-27 performance is almost identical to that of Australia at just over 1.1 in both cases. The UK and the Netherlands are the strongest performers amongst this group of countries.

In terms of the more detailed data on this research field Australia performs most strongly in Animal Sciences and has an RCI greater than 1.0 in all areas.

Finally, for research on Ecology and the Environment, Australia performs better than the EU-27 in aggregate terms but as with Agricultural Sciences the Scandinavian nations and the UK outclass Australia (and the USA).

Note: In the National Science Indicators database a paper is attributed to all author addresses. For multiple authors from multiple countries, each author gets full credit for the paper and the citations.

Conclusions

The proposed framework, as developed and demonstrated in this paper, could play a useful role in clarifying the nature and extent of the imbalances that exist between different nation's research capabilities – as reflected in relative citation performance in different research fields.

These results show that Australia's performance vis-à-vis both the EU and the USA is generally fairly strong to moderate – but rarely outstanding.

Perhaps most significantly, relatively small nations (in population, shares of global R&D and of global GDP) can and do perform relatively well in RCI terms. The advantages of large-scale R&D do not dominate the global science and innovation picture. Rather the nations that perform best in these terms are those that exploit the advantages of niche capabilities in which they can excel and address distinctively national objectives linked to geography and comparative advantage (both natural and knowledge-based).

This means that Australia may have the most to gain from enhancing its S&I cooperation with the smaller EU member states in the 'greater' Scandinavian region (the core of these countries plus geographical neighbours). If combined with Canada and the USA, cooperation with this subset of EU nations could provide the basis for productive multilateral cooperation in areas of key policy importance for Australia.

It is also important to note that Australia has much to gain from enhanced cooperation with a wide range of EU Member States. For instance, relative to Australia, Germany (a major force in EU and global science and technology) has particular strengths in geosciences, engineering, physics and space science.

Next steps

The next phase in this strand of FEAST's work will be to examine historical trends in RCI performance for a wider set of nations using this framework.

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