

Performance Targets in Academia and the Mathematical Sciences

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There is a widespread problem with research assessment in academia. The culture of ‘research metrics’ and ‘performance targets’ increases anxiety, pressure, and insecurity, and “transforms research into an auditable commodity”.¹ The problem is not limited to our discipline of mathematics, or to Australia, but the nature of mathematics, and existing Australian institutions, make some aspects of the problem particularly acute.

In order to address this situation, we have endeavoured to explain the problem as we see it, and propose some reforms and solutions.

Our perspective. The authors are pure mathematicians, but make no claim to represent every mathematician, pure or otherwise. This article is based on our personal experience, numerous discussions with our national and international colleagues, and our reading of various literature (including the listed references). We do not expect that every mathematician would agree with everything in this statement, but we believe that the views expressed here are broadly representative of mathematicians in general, and need to be heard. The main purpose of this note is to initiate a discussion, questioning the status quo and planting seeds for change.

The problem with numbers

Researchers everywhere face constant scrutiny and assessment of their research ‘performance’, through ‘metrics’ such as numbers of publications, numbers of supervised students and numbers of grant dollars awarded. These metrics all have one thing in common: *numbers*.

As mathematicians, we are very well placed to assess when numbers are appropriate measurements. We assess that numbers are *not* an appropriate measurement of the research of academics, and in particular of mathematicians. The measurements provided by numbers are usually inadequate, often unhelpful, and sometimes misleading. As the International Mathematical Union has stated:

Nothing (and in particular no semi-automatized pseudo-scientific evaluation that involves numbers or data) can replace evaluation by an individual who actually understands what he/she is evaluating.²

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Moreover, numbers provide a false sense of objectivity and represent an application of commercial practices into academia which is questionable at best:

The concept of ‘auditing’, probably first developed in a business context (accounting and then management), has now permeated many parts of Western societies. It is based on the belief that uniform, comparable, objective, evaluations of almost anything, people, organizations, companies, products etc., are possible. In particular, many funding bodies are now so convinced of the importance and universality of the evaluation of scientific activities that they tend to insist on using their evaluation rules, often based on semi-automatized ‘objective’ criteria such as Key Performance Indicators (KPI), even though most experts agree on the fact that these methods are not well-adapted to science in general, and to mathematics in particular.³

Views among mathematicians may vary on the legitimacy of regular performance assessments. Many colleagues might be comfortable with the idea that maintaining an academic position should require ongoing demonstrations of progress (however that can be measured). On the other hand, some might find any such requirements an intolerable imposition. Having essentially no metrics did not prevent other countries (like Germany or France) from developing a strong international presence in research, with world-leading mathematicians.⁴

Performance targets

Performance targets exist at several Australian universities, but not all. Targets may be in the form of ‘minimum’ requirements or ‘expectations’ as to performance; they may also be ‘aspirational’.

Targets may come in various categories, such as:

- grant income;
- postgraduate students supervised; and
- research outputs, for instance as measured by ‘high-quality’ publications per year.

Of course, other categories are possible, but the above are typical. Academics may also face performance targets regarding their teaching, service, leadership or other aspects of their role. But our focus here is on *research* performance targets.

Grant income. The first and most onerous barrier is the requirement of a minimal level of research income. The numbers might often not be very high, especially relative to other disciplines; but the situation in mathematics, sadly, is such that *any minimum requirement greater than zero dollars is onerous*. For many mathematicians in Australia, especially pure mathematicians, the only significant funding source is the Australian Research Council (ARC). One either has a grant and meets the target, even an ‘aspirational’ one; or one does not have a grant, and fails to meet the minimum target. A vast disproportion between worthy applicants

and available funds means that the success rate is very low (usually around 19% for Discovery projects and 16% for the DECRA scheme, as seen in the 2018 round). Success is skewed towards more senior, established mathematicians with a record of previous grant success, in a self-reinforcing dynamic.

In this context, a lack of funding cannot reasonably be interpreted as an indication of low-quality research. There are many factors that influence whether a grant proposal is successful, but most of these are out of the control of the applicant; and there are more general issues with the ARC grant system, including the following.

- The efficacy of the expert assessment process is questionable. Partly this may reflect the very small number of mathematicians on the College of Experts, but it also reflects the fragmentation of the discipline and the small size of the Australian mathematical community. It can be hard for mathematicians to understand recent results even in adjacent sub-fields; and some fields, though large and important globally, are tiny within Australia. Even excellent assessors may struggle to appreciate the details of every application they are asked to assess.
- The ARC grant system is driven by high quality and impact, but the impact of mathematical research can often be hard to measure. Citation numbers are lower than in other fields, and even top journals have relatively low impact factors (see below under ‘Research Outputs’).
- Since mathematics rarely needs expensive equipment, grant funding in mathematics is largely devoted to paying for travel costs and personnel. Personnel costs, for postdocs or PhD students, make up the bulk of funding. While it can be beneficial to have more postdoctoral researchers and PhD students, they are not usually as crucial as in, for example, laboratory sciences. Moreover, as outlined under ‘Supervision’ below, most mathematicians only have limited capacity to effectively supervise PhDs and postdocs. For example, a full professor who wants to meet ‘aspirational’ targets would likely need a continuous record of significant grant success; this can create a supervision workload which in fact hinders research progress. Given the enormous amount of time and effort required to put together a competitive grant application,⁵ and the low likelihood of success, it may often be reasonable for potential applicants to conclude that the cost outweighs the expected benefit.
- A longstanding concern, not limited to mathematics, is that short grants of around 3 years significantly restrict research ambitions by forcing research programmes into incremental short-term outcomes. Many mathematical breakthroughs have required long-term commitment without any guarantee of success, nor any partial outcomes along the way.

These problems derive not only from the specifics of the ARC system but also from the nature of mathematics itself. Often all that is needed to perform research is time, pen and paper, library access, perhaps a computer, and peace and quiet. As the American Mathematical Society states, “*many well respected, productive mathematicians receive little or no external support for their research*”.⁶

Despite these issues, we do not want to discourage colleagues from trying their luck: if they require funding for a research project, then it makes sense to apply for a grant. However, our experience is that incentives and rules set from above by university administrators lead to more time spent on grant applications than would be justified by purely academic considerations. At the very least, if university administrators seek to increase grant income and encourage more grant applications, they should expect more successful *and* unsuccessful applications as a result, and refrain from drawing any inferences of poor performance in the latter case.

Supervision. A minimum target for PhD supervision is also problematic and onerous, especially for junior academics. The American Mathematical Society discusses this in a cultural statement:

In some disciplines, directing dissertations is an integral part of a research program for every scholar, both young and old. In mathematics, however, this is not the case; it is unusual for a young (untenured) mathematician to direct Ph.D. students. As in other disciplines, a pre-tenured mathematician must focus on establishing a research program, including the publication of his or her research. Helping an advisee mature into an original researcher is labor-intensive and, unlike in the laboratory sciences, does not necessarily further the advisor's own research program. In addition, the advisor provides students with problems which, in many instances, he or she would otherwise solve, publish and receive credit for.⁷

The relationship between a PhD supervisor and student in mathematics is closer to that of master and apprentice, than to that of laboratory scientists. While PhD supervision may certainly be useful and beneficial for some junior academics, in the culture of mathematics it is simply not something that junior academics often do. Setting a minimum target for PhD supervision (especially for junior mathematicians), however, interprets this culture as poor performance. Again, this interpretation is wrong. A lack of PhD students cannot reasonably be interpreted as a failure to perform as a mathematician.

A direct calculation from the Mathematics Genealogy Project suggests that 78% of supervisors in mathematics have 5 or fewer PhD students over their career.⁸ Even tenured professors at world-leading institutions have a modest supervision load. A performance target that requires mathematicians to supervise 1–2 PhD students continuously throughout their career is difficult to satisfy for the vast majority of mathematicians, now and historically; such a requirement is in sharp contrast to the culture of supervision in mathematics.

Lastly, when pressure to supervise PhD students leads to accepting unsuitable candidates, this can be detrimental for all concerned.

Research outputs. Numerical targets for papers published are generally less onerous, but can easily become so. In any case, we think any numerical measure is inherently flawed. As the American Mathematical Society states,

publication practices differ from [other scientific] disciplines in several fundamental ways. . . . Mathematicians tend to publish at rates that are modest compared to some other sciences. . . even some of the best young mathematicians publish relatively few papers.⁹

Indeed, the American Mathematical Society concludes that “*when judging the work of most mathematicians, the key measure of value for a research program is the quality of publications rather than rate*”.

The problems with such numerical measures are, we think, numerous. Publication rates vary significantly between different mathematical disciplines; a target which might be easy for one researcher to achieve will be unrealistic for another. The best mathematics journals publish far fewer papers per year than top journals in other disciplines. If only ‘high quality’ publications are to be counted, then an official list of ‘high quality’ journals must be maintained, which is difficult since “the mathematical literature is spread among a wider collection of journals than in most related fields”.¹⁰ Being restricted to journals in a given list can hinder collaboration since different institutions may have different lists.

Strong research mathematicians write outstanding research papers. These papers often appear in journals with name recognition, although not always. For example, Professor Ian Agol, at the University of California, Berkeley, was awarded a 2015 Breakthrough prize in mathematics, worth millions of dollars, for his proof of the Virtual Haken Conjecture. The proof was published in the relatively unknown journal Documenta Mathematica. Additionally, strong researchers often publish frequently. But not always. Some of the highest performing mathematicians globally publish at rates that would fail minimum research targets. For example, Andrew Wiles went five years without publishing anything before announcing the proof of Fermat’s last theorem. Fields medalist Maryam Mirzakhani published relatively few papers in her career, with several two-year gaps in publication.

Alternatives

Abolition? Academics are, by their nature, highly motivated. In order to obtain their existing positions they have already achieved research success. It is arguable that performance metrics of the type discussed above do more harm than help, pressuring staff and diverting their efforts into unsuccessful grant applications, short-term incremental research, and bureaucratic requirements, at the expense of bold vision, deep thought, and fundamental breakthroughs. As Philip Moriarty

(Professor of Physics at the University of Nottingham) recently put it:

Here's my advice to senior university managers: put aside the fixation on flawed metrics and trust your staff. I know — scandalously naive. But try it as an experiment. *The vast majority of academics are hard-working and highly motivated: the sector would collapse if we didn't go the extra mile (one never taken into account by the metrics).* If researchers are producing high-quality work, they should be rewarded for doing it as efficiently as possible. They should no longer be coerced into over-egging the pudding to meet targets designed to pocket as much funding from the public purse as possible.¹¹

The abolition of performance metrics, by removing all the difficulties outlined above, would restore some of the freedom that has been lost within the academy in recent times. We believe it would release a vast amount of time currently squandered on fruitless efforts, redirect efforts towards more beneficial ends, and unleash bold new research potential.

However, if abolition is too bold a step in the present political and institutional climate, and regular performance assessments are still to be made, then we make some suggestions below. These suggestions should not only be applied in the discretionary considerations of probation or promotion committees. Academics should not have to place themselves at the mercy of a committee's benevolence; they should have the security of formal written rules to this effect.

No minimum targets for grant income and supervision. As explained above, the present system ensures that many excellent mathematicians will be unable to fulfil minimum targets. There are simply not enough grants or excellent PhD students. A lack of grant income or PhD students does not indicate a failure of research performance. If a minimum target must exist relating to grants, an *expectation to apply* for grants is more viable.

As a general rule, a researcher should apply for a grant if it is academically appropriate. Training PhD students is an important national priority, but this should not happen at the cost of quality and excessive supervision load. Academics should take on PhD students when they have a suitable project, the time capacity to supervise, and a sufficiently qualified candidate. Supervisors should be able to take the time to develop the research potential of their students, without pressure to continually take on and graduate more students.

Peer-review over numerical targets. Above we have identified several problems with numerical targets. The judgment of an expert is a much better alternative. To reiterate the International Mathematical Union,

Nothing (and in particular no semi-automatized pseudo-scientific evaluation that involves numbers or data) can replace evaluation by an individual who actually understands what he/she is evaluating.

As mathematicians, we find the pretence that such numbers present an objective assessment of our research particularly objectionable. It is a travesty of arithmetic.

On a day-to-day basis, supervisors can determine whether an academic is performing well. The existence of research outputs, active collaborations, and seminar talks can easily be observed. For probation and promotion, this process can be formalised with external referees (which happens already in some places).

Using expert review presents some of its own issues — appropriate experts must be found, and their time must not be taken up with evaluating colleagues — but we prefer it to the fake objectivity of numerical metrics.

Reward rather than punishment. If numerical metrics must remain, then they are much better used to identify excellence, than to punish those who fall short. Academics often work outrageously long hours, often self-imposed. They are genuinely motivated to apply for research grants when necessary and appropriate, and to publish work in prestigious journals. If they are lucky enough to secure grants, publish papers in top journals, and attract PhD students, they should be rewarded for it. But punishing mathematicians without grants in a system which leaves most mathematicians without grants, or for not having PhD students in a culture where they do not exist, creates undue stress in an already overworked academic environment and is needlessly cruel.

We note that to some extent this already happens: some universities internally reward academics who apply for grants.

Further indications for excellence. Some further indications of successful performance by research mathematicians are listed below. They are usually not captured in any numerical assessment system. (We do not suggest that new metrics be invented to capture them!)

- Participation in an international research community by speaking at conferences, workshops, and seminar; invitations to share research internationally.
- Organisation of conferences, workshops, and seminars; attraction of funding to organise conferences and bring strong researchers to the home University.
- Requests to referee and review papers and books, and to sit on editorial boards.
- Receiving awards for achievements.
- Having colleagues who write in support of their research activities upon request. Opinions of experts are solicited for most promotion applications, but are not always required for probation or in cases that merit special attention.

Conclusion

It should not be thought that onerous performance metrics have no effect on the quality of research. The effect is quite direct: effort must be diverted into continual, necessarily predominantly unsuccessful, grant applications; students must be attracted and trained; publications must keep ticking over. Longer-term, more fundamental research problems become more risky. Many mathematicians, and especially pure mathematicians, can expect to have zero grant income much of the time.

The situation was epitomised by Peter Higgs. After being awarded the 2013 Nobel Prize in physics for the discovery of his eponymous boson, he declared

Today I wouldn't get an academic job. It's as simple as that. I don't think I would be regarded as productive enough.

Higgs described how he had become “an embarrassment to the department when they did research assessment exercises”, kept on only because the authorities thought he “might get a Nobel prize — and if he doesn't we can always get rid of him”.¹²

The effect of constant performance assessment on the mental health of researchers should not be underestimated. There have even been extreme cases of suicide,¹³ tragically exemplifying these issues.

Notes

¹C. Shore, S. Wright, ‘Audit culture and Anthropology: Neo-Liberalism in British Higher Education’, *Journal of the Royal Anthropological Institute* 5(4), Dec 1999, 557–575.

²‘Recommendation on the evaluation of individual researchers in the mathematical sciences’, endorsed by the IMU General Assembly on Aug 11, 2014: www.mathunion.org/fileadmin/CEIC/ICM_2014_panels/Evaluation_of_individuals_FINAL.pdf.

³Ibid.

⁴List of Fields medalists per country shows that France and Germany are second and fifth, respectively: https://en.wikipedia.org/wiki/List_of_countries_by_number_of_Fields_Medallists.

⁵D. L. Herbert, A. G. Barnett, N. Graves, ‘Funding: Australia's grant system wastes time’, *Nature* 495, 314 (21 March 2013), www.nature.com/nature/journal/v495/n7441/full/495314d.html.

⁶‘2008 Statement: The Culture of Federal Support for Academic Research in Mathematics’, www.ams.org/profession/leaders/culture/CultureStatement08RevOct09.pdf.

⁷‘The Culture of Research and Scholarship in Mathematics: Directing Ph.D. Theses’, 20 September 2015, www.ams.org/profession/leaders/culture/DirectingPhDThesesfinal.pdf.

⁸Mathematics genealogy project, ‘Graph structure’, <https://genealogy.math.ndsu.nodak.edu/extrema.php>. The data includes 229,714 mathematicians as of 18 June 2018. Over 90% of them have 3 or fewer PhD students. There are 55,729 supervisors listed (i.e. who have supervised at least one student) and 43,240 of them have 1–5 students.

⁹‘2006 Statement: The Culture of Research and Scholarship in Mathematics: Rates of Publication’, www.ams.org/profession/leaders/culture/CultureStatement06.pdf.

¹⁰Ibid.

¹¹P. Moriarty, ‘The use of raw grant income as a performance target has got to go — now’, *Times Higher Education*, 18 June 2015, www.timeshighereducation.com/the-use-of-raw-grant-income-performance-as-a-target-has-got-to-go-now (emphasis added).

¹²D. Aitkenhead, ‘Peter Higgs: I wouldn’t be productive enough for today’s academic system’, The Guardian, 7 December 2013, www.theguardian.com/science/2013/dec/06/peter-higgs-boson-academic-system.

¹³C. Parr, ‘Imperial College professor Stefan Grimm “was given grant income target” ’, Times Higher Education, 3 December 2014, www.timeshighereducation.com/news/imperial-college-professor-stefan-grimm-was-given-grant-income-target/2017369.article; C. Davis, ‘Obituary — Professor Stefan Grimm, 1963–2014’, Imperial College London, www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_14-1-2015-17-40-44.

(All links accessed 18 June 2018.)



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