A new criterion for allocating research funds: 'impact per dollar'

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As long as the public funds scientific research, debate will continue on how to do so most effectively. For example, the NSF (USA) requires proposals to include activities addressing the 'broader impacts'[1] of a project. Similarly, starting in 2013, the Higher Education Funding Council for England will require applicants to articulate the societal and economic benefits of their research[2]. The criteria are so broad (by definition!) and vague that applicants do not know what to include, and evaluators have a difficult time making comparisons. Although these requirements are well-intended, it might be better if rather than focusing on vaguely defined 'broader impacts', granting agencies used a more potentially tangible criterion: 'impact per dollar' (or ¥, £, €, ₹, ₩…).

The impact of science is difficult to assess. For most of the 20th century, scientists were simply evaluated by the number of papers they published and the purported quality of the journals in which the papers were published. Until the development of electronic databases, determining the impact of any one paper, never mind one author, was a time-consuming and tedious work. As electronic databases became more widely available, it became possible to obtain the impact of any paper, group of papers, author, or group of authors.

The digital age brought forth another change. Previously, we used to read printed journals; so a manuscript published in a high-profile journal would have had a greater chance of being read than one published in a more modest journal. Now, researchers are more likely to conduct web-based literature searches and read not entire journals, but rather specific articles from a wide variety of journals. Hence, as long as the journals are listed in the main databases (i.e. *Web of Science*, *Scopus*, or *Google Scholar*) and their articles are available electronically, papers can be read and assessed based on their own merits, not the journals'[3].

Finally, the information age facilitated the development of many other impact measures[4]. Here, no attempt will be made to delve into the vast literature of bibliometrics, nor to settle any disputes among experts in the field. Nevertheless, the most widely accepted measures still rely, in some form or another, on citation counts, and in the last few years the scientific community seems to be coalescing around the *h*-index[5]. An author's *h*-index is the number (n) of publications that have $\geq n$ citations; thus, it integrates productivity (number of papers published) and the impact of these papers (citation rate) into a single number. Several variants of the *h*-index have already been developed[6]. These *h*-type indices can be used to evaluate journals[7], a group of researchers[8], papers published or cited during any given time-span, or any other meaningful group of papers[9].

Although the *h*-index is now gratuitously and indiscriminately reported (mine is 12), Hirsch[5] initially intended it as an objective measure specifically meant to compare researchers for recruitment, advancement and the award of grants, all of which entail the same basic process. Essentially, a committee examines the feasibility of an applicant's proposal, estimates its eventual impact, studies the applicant's record of achievements, and develops an opinion about the applicant's character from the reference letters. The problem is that committees seldom have the necessary time or level of expertise to fully understand an applicant's work, and as rejection letters unashamedly declare, committees ultimately give the job (or the grant) to the person whom they '**felt** would be a better fit for the department'. Impact measures are just numbers, and it could be argued that it is inappropriate to reduce a person to a set of numbers, but those numbers contain the biases and misconceptions that the entire scientific community built over many years, which are more attenuated than the biases and misconceptions that a small committee builds over a few days, or even a few minutes. Nevertheless, impact measures ought to be used as a guide to good judgement, not a replacement for it.

There is a discordance between funding, output and citation rate[10], which begs the question of why higher funding does not lead to greater impact. If the goal of publicly funded agencies is to get the greatest value for their money, or rather, 'our' money, the amount of money spent on a project should be proportional to its impact. Hence, to evaluate researchers and fund research projects, funding agencies ought to begin considering the impact per amount of money spent, the 'cost-effective impact'.

Naysayers might immediately argue that some fields are just more expensive because of the equipment and infrastructure they need, whereas others might argue that 'needs' expand to fit available funding. However, realistically, the allocation of funds among disciplines depends largely on political considerations, and to some degree, it ought to be up to those working in a field to 'sell' their product to the decision-makers. Whether they need it or deserve it, we could simply accept that some areas of research shall (continue to) receive substantially more funding, but that does not preclude using the 'impact per money spent' criterion within each discipline. This concept has already been used to assist in journal purchasing decisions by libraries[11], to explore the efficiency of funding within a given field[12] and to compare the scientific output of nations[13,14].

The impact of research funding is highly variable. Within our respective fields, we can find high-impact papers that cost nothing more than a graduate student's couple of months' small stipend. More poignantly, one of the greatest insights in the history of modern science came from someone who was financially outside the system, and at the time was supporting himself by working as a clerk at a patent office[15]. In contrast, without drawing attention to anyone specifically, it is easy enough to find grossly expensive studies with surprisingly low impact.

A benefit of using 'impact per dollar' as an evaluating criterion is that the issue of multiple authors becomes irrelevant. Projects that involve large teams of researchers reasonably ought to have greater impact, and if citations are the currency in which researchers are rewarded, common sense dictates that the reward ought to be divided among the authors, not magically multiplied by the number of authors. However, that is a problem for hiring committees; from a funding agency's perspective, it would not matter. If the agency's aim were to maximize impact per money spent, as long as an entire project with all its personnel were funded from a single grant, it would not matter whether the resulting paper(s) were authored by one person or 50. A principal investigator who could

cajole collaborators into working free, that is, to use their own scholarships or fellowships to join the project, would actually be rewarded by this system for getting more out of the grant. However, unlike the current system that favours senior partners[16], under this system, by joining a funded project and publishing without the benefit of a research grant, the status of a junior collaborator would actually increase. Assuming a high-impact paper is eventually published, the junior partner's 'impact per dollar' for that paper would actually be higher than the grant holder's impact per dollar, and this higher efficiency would be rewarded if the junior collaborator were to apply for his/her own grants. Hence, the balance of costs and benefits of junior and senior collaborators would shift, and the system would result in a decline in the number of large hierarchical research groups dominated by a single individual, and an increase in the number of independent researchers choosing to collaborate as equal partners in mutually beneficial relationships.

Similarly, research expenses covered by non-governmental organizations would not enter into the equation. From the perspective of publicly funded research agencies, the resulting impact would be a positive externality, putting no strain on the public purse. Again, these researchers would be rewarded accordingly on the next round of publicly funded grants, should they choose to apply. This system would yield closer and more transparent relationships between publicly and privately funded research. A potential conceptual problem might arise when a paper or project is supported by several sources. However, institutions already have both strict regulations and the necessary personnel to track all expenditures.

This practice of 'cost-efficient impact' might start in economies that are unable to increase their competitiveness simply by throwing more money into the problem. Assessment of first-time grant applicants would still have to rely on individual publication and impact measures. Furthermore, the power to make funding decisions would still be in the hands of a small group of elite reviewers and evaluators, but their decisions would be guided by – and would have to be well justified when they go against – the opinions of the entire scientific community. Additionally, different reviewing panels could be compared based on their ability to fund research of high impact, and be rewarded accordingly. The evaluation and application processes might be simplified when, to justify their research, applicants begin using readily available data instead of rhetorical embellishments inspired by wishful thinking.

Finally and most importantly, funding formulas can impact research output[17]; so different impact measures could be used to encourage quality or quantity, high or low-risk research, short-term or long-term impact, and single or multiple authorship. For instance, some seminal papers might take a few years to be noticed, but then enjoy an impressive staying power, whereas flashy papers might be immediately noticed, but then be quickly forgotten. Although individuals might be more interested in short-term gains, nations and their granting institutions, given their longer lifespans, generally ought to encourage and support long-term gains. Similar to the way central banks use interest rates to manage the rate of expansion of the economy, granting agencies could emphasize or de-emphasize fast turnover or long-lasting contributions by changing time limits on impact measures. In addition, granting agencies could set up programmes to balance recent (last few years) versus sustained (lifetime) contributions, or risky versus conventional research. For example, researchers doing conventional work would be those whose papers have a consistent impact per amount of money spent. In contrast, researchers involved in risky work would have a more variable output, with some publications having a high impact and others having limited success. Other concerns and considerations will certainly arise, to be followed by new policies and programmes.

Sousa[18] compared two fictional researchers with similar productivity, one working in the private sector and the other at a university. He pointed out that the private sector pays for its own research, whereas universities do not; furthermore, the private sector benefits financially from the patents and products the research yields, but universities usually do not benefit from the research itself, but rather from the grants it attracts. Sousa[18] argued that efficiency is rewarded in the private sector and wastefulness in the university system. The reason is that research in the private sector is based on a free market economy,whereas university research functions along the lines of a gift economy, in which scientists are compensated for their work, but the science is a gift to society. The value of these gifts comes from the influence they have on society – their impact. At a time of a global financial crisis, perhaps it is time that granting agencies establish policies that more closely reflect their mandates, and begin allocating funds to researchers and projects based on their demonstrated and/or expected impact per money spent. The adoption of 'impact per dollar' as an evaluating criterion would spawn a new era of collaboration and public accountability; researchers would no longer be admired and rewarded simply because of the size of their grants, but rather by whether they know how to use them.

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