LETTERS

Edited by **Jennifer Sills**

Grant funding: Playing the odds

A modified lottery could streamline grant-funding decisions.

FEW SCIENCE POLICY issues are more important than the allocation of research funding. Although a 2015 Report suggested that peer review has some ability to prioritize applications (*1*), it is not clear that the best science is being funded (*2*). There is evidence of poor precision and pervasive bias in peer review (*3*, *4*), as well as disparities in success rates based on seniority, race, and gender of the author (*5*–*7*). The current system is fairly effective in identifying the top 20% of applications (*1*), but fewer and fewer of those are funded (*8*). Selection of the best of the best resembles a lottery in its unpredictability (*2*), but one that lacks the benefit of being truly random, due to bias.

A modified lottery system could improve the fairness and efficiency of grant peer review. Given that reviewers are able to identify infeasible, poorly conceived, unoriginal, or otherwise seriously flawed applications, the first stage would use traditional peer review to do what it does best: create two pools of applications. The top 20 to 30% would be deemed meritorious, and the rest would be nonmeritorious. The second stage would use a lottery to select applications for funding from the meritorious pool. Applications deemed nonmeritorious would receive detailed critiques to allow applicants to revise and resubmit. Meritorious applications that make the lottery but are not selected for funding could remain in the pool for future lotteries, thereby saving both applicant and reviewer effort. (An alternative might be to give those who did not receive funding priority in the next round, but this would give the lottery some characteristics of a waiting list and quota system, which would have its own disadvantages.) As the process is implemented, policy details could be worked out to address issues such as how many lottery rounds applications will be allowed and whether those that consistently fail to obtain funding due to bad luck could be chosen for selective payment by program officers. Just as passively managed diversified stock portfolios that rely on random fluctuations of the stock market generally outperform active management based on expert predictions (*9*), a modified lottery-based funding strategy would maximize the return on society's investment in science by distributing funding as broadly as possible. Moreover, a precise determination of the percentage of meritorious applications remaining unfunded would be a powerful tool to advocate for increased federal budgetary allocations. If lotteries can be used to select individuals for military service, housing, or the receipt of scarce medical resources (*10*), perhaps they can also help distribute research funding more fairly.

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Undermined by overhead accounting

AT MOST U.S. INSTITUTIONS, an overhead charge (or indirect cost) averaging 52% (*1*) is collected on all research expenditures, except for equipment. However, equipment is defined by science funders such as the National Institutes of Health (NIH) (*2*) and National Science Foundation (NSF) (*3*) as an article of tangible nonexpendable property that is useful for more than 1 year and has an acquisition cost of $5000 or more per unit. This definition, which allows collection of overhead for equipment costing less than $5000, likely costs U.S. scientists collectively millions of research budget dollars annually (*4*).

If a piece of equipment costs $4999, the average effective cost to a grant is $7598.48. If the price of the same item is $1 more, then it costs only $5000 (saving more than $2500 on the grant). If a scientist is trying to decide between two identical pieces of equipment that cost $3300 and $5000, the scientist will be a better steward of research funds by purchasing the more expensive tool. The cheaper tool costs more on the grant and thus reduces the funds available for research. This perverted economic incentive encourages wasted money.

It is tempting to think that such small research expenditures are immaterial, given that routine scientific projects cost millions of dollars in total expenditures. However, purchases under $5000 often represent the majority of nonlabor–related research costs for standard research projects. Some of these expenditures are for supplies, but much of the core equipment used every day in labs falls into this under-$5000 category. A tiny fraction of overhead is normally returned to the department to be used for research, but the vast majority of indirect costs are used to subsidize administrative salaries and building depreciation (*5*), neither of which directly benefits research. On the contrary, these expenses often hamper research. The benefits administrators reap from overhead create a second perverse incentive: Administrators fight to maintain the arbitrary value of $5000 as the definition of equipment (*2*, *3*).

This problem is not new. However, now it is becoming even more damaging as it is effectively creating a de facto tax on the mass diffusion and development of free and open-source hardware (FOSH) for science. FOSH is hardware designed in the same way as open-source software; the designs are freely available for all to use and modify. FOSH is now growing rapidly because the costs of scientific hardware are generally only 1 to 10% of the cost of proprietary tools (*6*–*9*). Thus, a $40,000 proprietary tool can easily be replaced by an equivalent $4000 FOSH instrument, which will be penalized with an

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indirect cost of $2000. These savings are now possible because of digital manufacturing technology such as 3D printers, which enable both new science (*10*) and an increased ability to replicate scientific equipment (*6–10*). The relatively minor development costs of FOSH result in enormous returns on investment for scientific funding agencies, as tools are digitally reproduced thousands of times for the cost of materials (*11*). By removing the arbitrary capital cost of equipment, the effectiveness of research funding can be improved, and society's investments will pay larger dividends both directly and indirectly.

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Cultural costs of tropical dams

RECENT PIECES IN *Science* rightly call for greater examination of the environmental, political, and economic trade-offs of tropical dams. In his Feature news story "Power play on the Nile" (26 February, p. 904), E. Stokstad explores political uncertainties of the Grand Ethiopian Renaissance Dam. In their Policy Forum "Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong" (8 January, p. 128), K. O. Winemiller *et al.* herald the potential detriment to one-third of the world's freshwater fish species by unprecedented hydropower dam construction. In his Letter "Tropical dams: To build or not to build?" (29 January, p. 456), P. M. Fearnside asks a fundamental question about current development. Assessments of impacts of dams on riparian human populations typically focus on economic issues related to community displacement, or food security risks from loss of land or fisheries. However, riparian human populations stand to lose much more than land, food, and income.

Free-flowing rivers hold special significance in indigenous cultures. In the Amazon, the Shawi bathe in rivers, gathering strength from water carried down from mountains and ancestors (*1*, *2*). The Peruvian Kukama believe that people who have drowned in rivers and whose bodies aren't found live in underwater cities, communicating with relatives through dreams or shamans (*3*). The Gumuz people of Ethiopia's Blue Nile Valley—living in the shadow of the Grand Ethiopian Renaissance Dam's construction—have described the river as a second God, providing everything they need for living; most cannot imagine life without the river (*4*). A legendary water-dwelling creature—Mokele-mbembe, or "one who stops the flow of rivers"—has captivated explorers and locals of the Congo Basin for centuries (*5*). In the Mekong, many indigenous people believe that ancestral or animal spirits can influence flow and quality of water, and fear of mysterious creatures has prohibited fishing in certain areas (*6*). Native people of northern Thailand engage in ceremonial practices to show respect and gratefulness to supernatural beings thought to influence water resources (*7*).

We need better understanding of the implications of tropical dam proliferation for riparian human populations. An assessment of human and water security (*8*) that includes not only economics, politics, and environment but also culture would more accurately capture the costs and benefits of hydropower development and influence decisions on new tropical dams.

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