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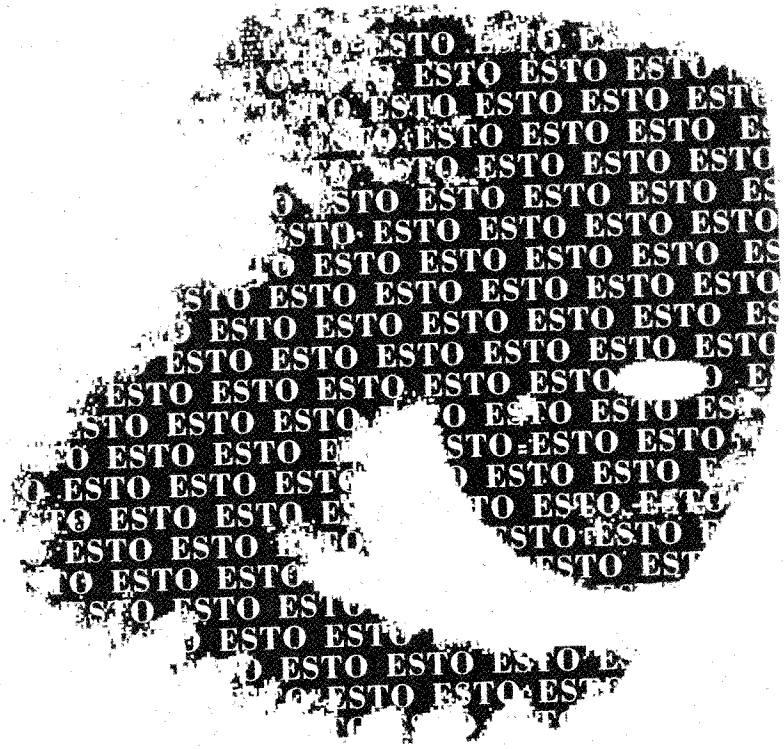

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EDITORIAL

Busy Bees Showing the Way

Dimitris Kyriakou, *IPTS*

A piece on the New York Times[1] recently discussed the apparent success of an experiment whose very conception is a testament to the limitless character of human imagination. Scientists were reported to have trained honeybees to seek minute traces of explosives. Even if bees have limitations (e.g. performing under adverse weather), they have certain characteristics that make their 'training' very promising. First, their olfactory sense is spectacularly sensitive. Second, in their hunt they leave no nook uncovered as they weave their way around the search area. Third, they can be easily trained – it has taken scientists, using sugar-water rewards, less than two hours to teach a hive of bees to eschew flowers and pick out a specific residue (2,4 dinitrotoluene) found in explosives such as TNT, in tiny concentrations. Fourth, once a few of them are trained, they transfer the newly acquired knowledge to the entire hive, in as little as a few hours.

In experiments involving twelve trained bee colonies at the Southwest research Institute in San Antonio, Texas only one or two bees per hour picked uncontaminated areas, whereas about 1200 bees per hour correctly picked the contaminated targets. The US Air Force Research Laboratory found that in its tests, trained bees picked the explosive chemical 99% of the time. Moreover, grain-of-salt sized transmitters are to be used in the next few weeks to track individual bees as they follow diffuse trails of bomb ingredients to a source.

Although one could suggest that such innovations could not be used in areas where human presence is high (e.g. airports), one can think of ways in which the trained bees can pick suspects in a crowd, without being even seen by the crowd. There is no space for this here, but think for instance of bees under a thin, porous surface over which passengers have to pass –their reaction when a suspect passes a few centimetres above them can indicate to security agents what and where they should more closely search.

The innovative idea therefore, even if originally funded by the US defense department's defense sciences office of the Defense Advanced Research Projects Agency (DARPA), can have important security implications and applications in non-defence sectors, such as civil aviation. Ideally, it should not therefore be limited to use by the US military.

Beyond the interest of the science and the ingenuity involved in this project, it is perhaps worth bearing in mind that it only started in 1998, received funding of 25 million $US from the US

The views expressed here are the author's and do not necessarily reflect those of the European Commission.

Diversity and Excellence: Considerations on Research Policy

Jordi Molas-Gallart and Ammon Salter, *SPRU*

Issue: The public funding of research operates in an environment of scarce financial resources. Focusing investments on only those centres, individuals or groups that can prove excellent/exceptional capabilities and performance is emerging among some policymakers and scientists as a popular policy option to maximize results. Yet, depending on how this approach is translated into policy measures, it may possibly result in a concentration of research funds and negatively affect the diversity of the scientific and technological base, undermining the potential for the development of new areas.

Relevance: The notion of networks of excellence is central to the current approach to the definition of the forthcoming Sixth Framework Programme, and is also a building block of the European Research Area. The ways in which such concepts will be translated into specific policy measures are still to be defined in detail. It is important to explore prospectively the possible implications of the ways in which the pursuit of excellence as a policy objective is translated into different policy proposals.

The policy problem: distribution of scarce research funds in conditions of uncertainty[1]

Research funding is an uncertain business. The outputs of research and development (R&D) are highly uncertain and skewed.

The skewed nature of R&D outputs has been demonstrated by a variety of studies.[2] For example, using several databases of inventions and innovations, Scherer and Harhoff show that "the top 10% capture between 48 to 93% of the total sample returns" (Scherer and Harhoff, 2000: 559). They argue that when dealing with technology policy, one should expect only 1 in 10 projects to be successful. Skewed distributions also occur when considering other research output indicators. For example, using academic citations we can see that a small minority of papers accrue the vast majority of citations, while most academic papers are never cited (Katz, 2000).

Research funding is an uncertain business. The outputs of research and development (R&D) are highly uncertain and skewed

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Excellent performance becomes the main criterion for the distribution of research funds as a means to concentrate limited R&D resources in a small number of world-leading research actors and, hopefully, to increase research outputs. Past performance excellence is likely to become, increasingly, an *ex-ante* necessary condition to become a receiver of further research funds.

Culling mechanisms and the reduction of diversity

Focusing on the support of excellence is only one side of the coin, the other being that other groups are likely to see their access to research opportunities curtailed. The confusion in the way the term "excellence" is used is partly responsible for this outcome. Often used but rarely defined, "excellence" is taken by many to be simply a synonym of good quality. If so, it could be possible for "excellence to be the norm". Yet, there is another aspect to its definition and use: "excellence" is also a comparative term, meaning better than the norm. In fact, the research techniques used to identify "excellent research" are comparative in nature: scoring mechanisms like the UK Research Assessment Exercise (RAE)[3] are explicitly based on comparative criteria, and the study of institutional performance based on impact indicators like article citations are based on the analysis of the distributions of an indicator or sets of indicators across a population. The groups that these techniques identify as excellent are excellent by virtue of their comparison with the whole population.

In this broadly used comparative meaning, excellent performance can only be achieved, by definition, by a very limited number of researchers or research groups. Under this interpretation, excellence is a relative concept, it only exists by comparison to a much broader population dominated by mediocre (i.e. average) performers. Without mediocrity, there is no excellence. It follows that focusing on excellence will mean "cutting off the tail" of the statistical distribution, corresponding to mediocre researchers (see below for some examples of how this would work in practice). Yet, the resulting distribution will again have a "tail", a better performing one perhaps, but still mediocre if compared with the rest of the survivors. Further, it is very likely that the skewed distribution of results and performance across the population of researchers will remain even after the population has been culled.[4] Under these conditions, the enduring pursuit of excellence by repeatedly eliminating trailing research groups will lead to a reduction in the number, and therefore diversity of research performers. Over time, the continuing reduction in variety would lead to the concentration of research funds to an ever-declining base of researchers.

Policy proposals: some examples

Focusing on excellent performance as the main criterion for funding is likely to increase the concentration of funds in those institutions that have a reputation for past excellence. The use of past performance as a key criterion for the allocation of research funds is becoming an increasingly common policy proposal. This model is now being accepted by many policy-makers attempting to raise research excellence by promoting "concentration" and "co-ordination" in funding, and explicitly seeking to reduce variety, which is seen to be expensive. The model can lead to a situation in which only a limited number of pre-selected institutions and individuals may be allowed to apply for research support.

For instance, in the UK, there are serious policy discussions on the development of new research funding mechanisms that will limit opportunities for those organizations with low Research Assessment Exercise scores. Research organizations that fail to garner a high enough score may be shut out of future research funding rounds. Another example of how this model would work in practice has

If excellence becomes the main criterion for the distribution of research funds, past performance is likely to become the main condition for receiving further research funds

If measures of excellence are based on comparative criteria, cutting funding for projects or organizations at the bottom of the ranking will inevitably result in an ever smaller "population" of organizations on which these comparisons are based

rapid expansion of the software industry that their work was fully appreciated. This pattern has occurred repeatedly in the history of the sciences (Rosenberg, 1992). Sir Robert May, the former Chief Scientific Advisor to the UK Government and Head of the UK Office of Science and Technology, suggests that in order to overcome the essential conservatism of institutions of science, it is necessary for research councils to promote diversity and "ambitious" research. May recognizes that funding "excellence" is not a sufficient policy option (May, 1998).

- *Diversity of sources of funding.* Proposed systems may end up producing concentrations of sources of funding as well as of recipients of funds. One of the main strengths of the US system of research is that there are a number of overlapping and competing funders of research. This competition among funders creates opportunities for new entrants to win resources and enables new areas of research to emerge (Pavitt, 2001). In comparison, European researchers have fewer sources to access when they search for funding.
- *Research plays different roles (including training).* There are numerous studies showing that research and innovation interact in a variety of ways (Salter and Martin, 2001), and that the outputs of academic research go well beyond the generation of new knowledge as embodied in scientific papers. It has been shown that a key benefit of publicly funded research to innovation is the development of trained problem-solvers (Pavitt, 1991; Steinmueller, 1994). Research funding expands the pool of talent for firms to draw upon when developing new products and services. Further, publicly funded research creates the possibility for new fields of inquiry to be developed and expands social choices about the development of new technologies.
- *Size matters.* The demand for scientists and engineers by industry has grown consistently over the past 50 years. In response to this demand, governments have expanded the size and breadth of the research system in which universities play a central role. Cutting off research funding to a large number of these universities would disconnect many students from the research process thus reducing the supply of scientists and technicians trained in research methods and techniques.
- *Excellence is not stationary.* It is possible to have a highly mobile population within a skewed distribution. In other words, those that perform at an average level at a certain point in time may develop excellent research in the future, and vice versa, excellent research groups may become complacent (particularly if their access to funds is made increasingly easy).
- *'Democratic' or inclusive funding mechanisms can help to achieve social cohesion.* In many OECD countries considerable attention has been focused on ensuring a more 'democratic' or inclusive distribution of research funding. Given the characteristics of cumulative advantage in science, it has been found that left to itself research funding tends to be highly concentrated in a small number of regions. Policy measures have been designed to address this problem. In the US, for instance, the National Science Foundation EPSCoR programme (see below) has been set up to support proposals from less favoured US States.
- *Uncertainty.* The problem faced by funding organizations is to determine *a priori* what will be excellent research. Under hypothetical conditions of full information and certainty, an efficient solution to resource allocation could be found. Yet, when luck and serendipity are important factors in the generation of research results, it is very difficult for peer review panels to know when or where excellence will emerge. Under these circumstances, research funding organizations have tended to select proposals from a variety of academic institutions, in

One limitation of "excellence-only" funding models is that they tend not to promote the kind of diversity that may be necessary to foster innovation

Excluding underperforming organizations will reduce possibilities for contact between students and the research process, thus possibly restricting the supply of future researchers

The Basque regional government in Spain is considering a layered approach to research funding as a means to promote diversity. The approach would use different sets of mechanisms to promote and support the research work of different types of units, from established research groups to groups with no previous research experience (Gobierno Vasco, 2001). In the US, the goal of ensuring more 'democratic' funding has recently been translated into the Experimental Program to Stimulate Competitive Research (EPSCoR) supported by the National Science Foundation and several US States. EPSCoR is designed to overcome the tendency towards concentration of research activities by providing special backing to States receiving a small share of total NSF research funds (0.7 percent or less averaged over a three-year period). Currently, 21 States and Puerto Rico are eligible to benefit from several support actions including funding for new research infrastructures and special arrangements when submitting research proposals to the NSF (National Science Foundation, 2002).

Conclusions

Focusing on comparative, past-performance-based measures of excellence is not enough to develop a useful policy framework. Particularly dangerous is to use such assessments of excellence to determine *ex-ante* who is eligible to conduct research. By closing off opportunities for new entrants, such an approach may reduce the variety and breadth of the research base and is likely to have a pernicious impact on new fields of research. Besides, it is important for funding agencies to realize that the distribution of research outputs will remain highly skewed regardless of whether they adopt the "excellence-only" model. By definition, average research can never be eliminated and it is futile to pursue its eradication.

Alternative approaches encourage diversity in the research base by using a variety of funding instruments. The choice now faced by governments is not to fund average or excellent research, but rather to further concentrate research funding in the hands of the few or aim to support diversity and generate depth in the research system. To fund high quality research, agencies should continue to rely on peer review of research proposals rather than narrowing their future choice by concentrating funds in a small number of groups with a track record of excellent performance as identified by the limited set of indicators at our disposal. Review methodologies must attempt to ensure that this process does not cut off the sources of variety in the research system. Space needs to be created for ambitious research, research that does not fit inside the bounds of traditional disciplines and does not appear to fit conventional models of excellence. Research funders can beneficially promote diversity by focusing on the funding of a broad range of research projects, from a wide range of different organizations, judged by the quality and novelty of their proposals. This process could be aided by review panels composed of experts drawn from a variety of different perspectives and backgrounds, including academic and non-academic communities. Funding new entrants is likely to remain expensive and generate research that is unsuccessful. However, this is a price worth paying in order to sustain diversity.

These are important considerations when notions of excellence are translated into policy practice in the context of the forthcoming Sixth Framework Programme. We would argue that a portfolio approach to funding would require the maintenance of a variety of instruments, structured so as to enable new entrants and smaller research groups to benefit from research funding and European collaboration. The new FP6 is moving towards a mixed economy model with networks of excellence, integrated projects and open project competitions. For instance, the networks of excellence are likely to be a key tool within the new set

A portfolio strategy of support recognizes that only a few successes will pay off on a large scale and is based on the projection that generous returns from relatively few successes will also cover the cost of many less successful projects

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