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Public Funding of University Research and Graduate Programs

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The Problem

The system of public funding of research at universities, which is inseparable from graduate education, has recently been intensely discussed. Although this system has been quite successful compared to other countries, some changes are being made or are under consideration. They might either yield further improvements or inflict damage.

To avoid the latter outcome, it is important for the broad research and educational community to participate in this discussion with an understanding of the basic questions and past experience. What are the basic principles to follow? Which have worked well? Which have failed?

The present invited paper [1] addresses these questions. It begins by an attempt to characterize an effective and fair system by ten principles which are largely drawn from successful past experience in the United States. It continues by a discussion of some reservations, and ends by considering some historical experience and describing an example to avoid.

Principles that Have Worked

The successful past experience in the United States can be characterized by the following ten principles, which should not be violated by any future modifications of the present system.

1. *Government funds for basic research should be spent* mainly *in the form of* research grants to individual principal investigators *(university faculty members), based on their em unsolicited proposals.*

   Experience with the classical NSF system in the U.S. has proven that such grants, introduced on a large scale in the late 1960's, are very cost-effective and most likely to lead to original ideas. This system has enabled the United States to do very well, for example, in civil engineering research despite the fact that the financial outlays in this field have, in fact, been much smaller than in some other countries.

   Since the proposals are unsolicited, does the government have any control of the research direction?—Yes, but only in a very general way. The relative emphasis on various fields, such as robotics, high-performance materials, AIDS, etc., is controlled by the amount of funds wisely (or unwisely) allocated by the government to each field.

2. *The individual principal investigator who succeeds in receiving a grant should be the* director *of the funded project*

   —in the full sense of the word, even if he is a 27-year old assistant professor. In our system in the U.S., the director alone is responsible to the government agency for the technical aspects. He alone decides whom to hire as his research assistant, whether to use an in-house or outside secretary for typing, and whether to attend a conference abroad (provided of course, sufficient funds are available). A project director is normally allowed considerable freedom to reallocate funds from one subaccount to the grant of another, for example, from technician salaries to computer purchases, or from postdoctoral stipends to conference travel. He is free to tell his assistants that he does not care about their working hours, *provided that* they work hard enough to be able to demonstrate good progress at the weekly research sessions. Treated this way, many graduate students are sufficiently motivated to be at the computer or in the lab even at 11 p.m.! Senior faculty members, the department chairman and the dean, cannot forcibly intervene in scientific matters of the grant. This is in stark contrast to some West European institutes, and even more, former East-European institutes, in which the senior professor-director totally controls the type of research undertaken by the junior faculty members, whether or not they can travel to a conference, and so forth. The responsibility of the university, which has previously examined and approved the detailed proposal for the grant, is to provide the means for carrying out the research (rooms, equipment, an academically stimu-

[1] This paper is based on the author's speech that was delivered in Czech at the Czech Technical University (ČVUT) in Prague on Nov. 14, 1991 after conferral of an honorary doctorate, and was published in Czech in Bulletin of ČVUT 1991 (No. 3–Dec.), pp. 5–9. A modified version of the present ten principles was published in English in Materials and Structures (RILEM, Paris), Vol. 25 (1992), pp. 248–252.

lating environment, accounting, etc.), while ensuring that no rules are violated and preventing conflicts with teaching, other university business, or other research projects.

3. *Although every known system has some faults, the* anonymous peer review *is the best for selecting basic research proposals for funding.*

   In this system, anonymous reviewers—peers in the profession selected as leading specialists in the subject—evaluate both the research proposal and a report on the accomplishments under the previous grant. They also scrutinize the overall research record of the proposer. The evaluation of results is most thorough at the time the investigator applies for a subsequent grant in the same field.

   The officers of the granting agency who select the reviewers have great power. While they need not be specialists in the same narrow subject, they must have broad research experience themselves. They attend many conferences and stimulate research workshops, at which they can hear the researchers argue and criticize each other.

   Selecting unbiased reviewers is, of course, a difficult and sensitive task. After some experience, one inevitably finds that there exist certain experts who usually recommend rejection of any proposal, and others who usually recommend approval of any proposal. Such reviewers should not be selected. Furthermore, the reviewers must be neither enemies nor close friends of the proposer. Most reviewers, however, are motivated to do an honest job. Moreover, they do so without a fee, because they consider it a moral duty of an active scientist and because they want to achieve a good image for themselves with the granting agency.

   Nevertheless, not every reviewer is impartial, and for this reason it is desirable for a country to have a variety of granting agencies, so that if a proposer thinks the evaluation from one agency has been unfair he could try his luck with another agency. In the U.S., this variety is helped by the fact that the branches of the military fund much basic research whose application is not only military. This has another advantage: the military officers typically are excellent and technically knowledgeable administrators, and in this manner their capabilities can be in peace-time utilized more effectively.

   Fairness of review may further be helped by supplementing the peer review with a review by a panel of experts, as recently practiced by NSF. Unfortunately, however, many proposals have recently been reviewed by such a panel alone. This cannot adequately replace the peer the review by mail, for two reasons: (1) Even if the panel consists of the most illustrious scientists, the few top experts in the precise subject of each individual proposal cannot be represented on the panel, although they are reachable by mail, and (2) the time constraint for the meeting of any panel is inevitably too short for a really thorough evaluation.

   There is a danger that can wipe out the benefits of a good review system—egalitarianism. There exist countries where (sometimes even despite peer review) nearly every professor somehow receives a grant but none a large grant. It is important for the governmental agencies to realize that getting a research grant must not be an entitlement of any professor.

   For small countries, there is an additional problem. The number of researchers in some particular subject is often so low that the reviewer must expect the proposer to correctly guess his identity. This, of course, defeats the system. In that case, one must solicit anonymous reviews from other countries. But then it might be difficult to get a reviewer to respond without offering him an honorarium (this is actually done, for example, by Saudi Arabia). Requests for reviews from abroad have already become frequent, for example, in Canada, Australia, South Africa or Israel.

   In this regard, good relations with emigrants can help their native country. Countries such as Korea or Taiwan suffered massive emigration of their brightest scientists to the U.S., but they never regarded these emigrants as traitors. Rather, they cultivated their friendship. Later, after acquiring a wealth of experience, many of these scientists started joint projects, served as reviewers or consultants for their native country, and some returned as well-paid professors or institute directors. No doubt this has been a factor in some economic miracles.

4. *Research grants should pay the* full *cost of research, not just the incremental costs.*

   This means that the grant to a professor should substitute for a part of his academic salary. It should also provide him additional salary (which is done in the U.S. in the form of the so–called "summer salary"). It should pay for his assistants, technicians, and possibly an outside consultant on a vitally related subject. It should pay for the proportional costs of his secretary, conference travel, health and retirement insurance, computer and testing equipment, office supplies, mail, phone and fax, and, of course, the administrative overhead, which is essential for the well-being of a private university. Without this, the full cost of research is not known to the government and cannot be compared to other financial outlays according to the principles of market economics. When the country's system includes competing public and private universities, fairness in their relative treatment is impossible without such knowledge.

5. *Outstanding research should be* rewarded, *especially financially.*

   Financial rewards are a tremendous stimulus for most people, including researchers. By winning a grant, an American professor can earn additional salary (which is normally limited to one-third of his academic salary). His salary level, as well as promotion, depends heavily on his research accomplishments (even though the amount of granted funds cannot measure these accomplishments precisely). These rewards provide a powerful incentive for productivity (the number of research proposals submit-

ted by Northwestern faculty members nearly doubled after the university introduced a system in which one-half of the professor's academic salary substituted from his research grant is returned to him as discretionary monies, from which he can freely buy a computer to use at home, pay for a study trip abroad, or hire an additional assistant to typist).

Bureaucrats can destroy these incentives. Many of them strive (or are forced by regulations) to prevent any academic from gaining extra income, regardless of performance. It is a curious mind-set; they consider it normal when a singer or a boxer is rewarded for top performance by millions of dollars, but they seem to envy a top-performing researcher every petty honorarium, consulting fee, "slush" fund, or other perk. They try to smuggle into the system a variety of new restrictions, even when the paperwork to enforce them costs more than a researcher's gain.

6. *The conduct of research at a university should be* objective-oriented.

The only thing that matters in research is what is achieved. Thus, the progress of the team members toward the objectives must be regularly evaluated. It is counterproductive to dwell on formalities such as adherence to working hours. The professor, may be more effective writing his research articles at home. An assistant, naturally, must not miss research meetings and classes, but if he wants to sleep till noon or take a day off, he should be told—fine, *provided that* he is self-disciplined enough to work for a sufficient number of hours and be able to meet the objectives by demonstrating good progress at weekly research meetings. To succeed, many assistants at Northwestern often voluntarily work over 60 hours a week, at nights and on weekends. Such liberty helps motivation and healthy competition.

7. En-bloc *funding of large research centers or institutes should be* exceptional.

Such funding is appropriate only when there is a particular need for a rapid advance regardless of cost, or when it is necessary to rapidly enforce collaboration of many scientists with different specializations, rather than waiting for it to happen spontaneously (one early example was the Manhattan Project). Typically, such large centers distribute funds to their members on the basis of in-house reviews which have two disadvantages: (1) they tend to be tainted by local politics, buddy systems, and personal animosities, and (2) they tend to be superficial and cannot match the classical NSF peer review system because the best experts to evaluate one member's proposal or performance are normally scattered throughout the country and world. While a few principal investigators in the center usually are truly outstanding, many others would often be unable to get funding on their own and thus they get a "free" ride. Moreover, the external evaluations tend to be biased, at least subconsciously, in favor of the center, for the simple reason that the governmental administrators and politicians who approved the funding of a large center have much reputation to lose in case the funding were discontinued. Another factor that tilts the scale toward large centers is that they can devote financial and administrative resources to publicity while individual investigators cannot.

Consequently, in comparison to individual grants, the cost-to-benefit ratio of the center mode of research is normally higher. This ratio is further lowered by the cost of an additional layer of administrators at the center level, which is avoided in the case of individual grants. The worst effect of funding entire centers through a single grant is that it siphons away funds that could otherwise be available for grants to individual investigators. There has recently been considerable polemics on this subject, and the politicians who generally favor governmental regulation of the economy won a great expansion of such en-bloc funded large centers. What these politicians overlook is that the center-mode of research funding is nothing new. It has been practiced in Western Europe, with a relatively low cost-effectiveness. On a particularly large scale and with lavish funding, it was practiced in the former communist countries, where the results have been dismal indeed, as the governments of those countries now generally recognize.

One aspect that deserves scrutiny in this regard is the recent policy of establishing large new research centers. Rather than recruiting the best from around the nation, a newly created center inevitably must take as its members whoever happens to be available at the institution that got the center grant. Some may be outstanding, but not most. One might argue that the opposite would be undemocratic, elitist, but the ultimate price is inefficiency in the use of public funds allotted to research, which damages everybody.

8. *Universities* are, on the average, more efficient in basic research than institutes that do no teaching.

A critique of the Institute for Advanced Studies by Feynman [2], a Nobel-prize winner from Caltech, is a case in point — even an assembly of the greatest brains did not guarantee spectacular results. How many professors have had the experience that a new idea comes to mind or an error is noticed exactly while writing on the blackboard, in front of the class? Students often ask surprising questions, challenging the professor. If no good idea is coming to the professor's mind, at least he can avoid frustration by satisfaction from good teaching. Then a good idea is more likely to come to his mind eventually.

9. Relevance *of scientific research to industry needs to be fostered in certain fields by incentives for collaboration.*

Certainly it is inappropriate to grant taxpayers' fund to profit-oriented industrial firms. However, cooperation of

[2] R.P. Feynman, "Surely you are joking, Mr. Feynman!", W.W. Norton & Co., New York 1985.

university researchers with industry does not happen automatically and needs to be encouraged. This is particularly important in all fields of engineering and applied science.

It is thought that such cooperation is better achieved by centers that individual investigators. But the latter can be influenced to do the same by various incentives—for example, by allocating additional grant funds solely for that purpose.

10. *Finally, it is beneficial if the country's system includes not only public but also* private *universities engaged in research.*

Obviously, the latter provide competition to the former, and thus force them to be equally efficient. For example, if a private university can thrive with an overhead rate of 52%, it is unlikely that a government auditor would approve a rate of 80% for a state university.

Some Reservations

Some reservations could, of course, be discussed. Many believe that the system just described creates a conflict between research and teaching, but this is an overstatement. The same is true, I think, of the publish-and-perish attitudes induced by this system.

Presently, most universities are having great difficulties in attracting to doctoral study American students, especially very good ones. This problem, for which the blame is placed by some on the present system, is particularly acute in engineering, and even more so in civil engineering. One reason, of course, is that employment and salary prospects are, on the average, not much better for engineers with a doctoral degree, and another is that higher incomes attract students to law, business, and medicine. However, another important reason, in my opinion, is that adherence to the free market ideas underlying the principles I just outlines tends to depress research assistant stipends, because outstanding foreign students are willing to come to America in large numbers for relatively low pay. If this is so, these principles need to be violated to some extent by creating special incentives. As already initiated, governmental funding agencies should grant the best American students special stipends for doctoral study.

Relevance of Some Historical Experience

It is instructive to recall the old system practiced up to the second world war. In those times, scientific research was generally conducted on a much smaller scale, with modest governmental funding, and in a more individualistic manner. This old system, in which Germany excelled, did not require formal education of a large numbers of scientists. It could rely on the small number of geniuses naturally occurring in a population.

A genius does not need much formal education. His development may even suffer from too much organized education. He needs only stimulation, interaction with learned scholars, and opportunity to study by himself, which is what the old system gave him. He will thrive under such conditions. He will educate himself despite inadequacies of the educational system. In fact he will become better than the same kind of person who has received thorough but closely guided education. The reason is that overcoming educational obstacles is in itself a very valuable educational experience. A determined, bright and inquisitive person studying alone, from books, often takes wrong turns, adopts wrong ideas, and consults texts taking contrasting approaches. But when he later eventually finds the right ways, the right ideas, he understands them better. He knows the reasons why it must be that way, and not any other way. Thus he understands the subject deeper than someone whose thought has been guided the right way all the time. Studying alone is harder, takes longer and, above all, requires more persistence, but for those who persevere and manage to arrive to the end, the final result is more than just knowledge—it is understanding. Moreover, the habit of self-education and unguided learning becomes invaluable when working at the forefront of research where no text, no teacher exist.

Awareness of these facts is important. In regard to applying technological discoveries already made, what matters (aside from economic and political aspects) is the overall educational level of the population, and the engineers in particular. But in regard to leadership of a country in actually making technological discoveries, what matters is not how well educated the population is as a whole, not even how well educated the engineers and scientists are as a whole, but only how good is the best tiny fraction among them. What produces such a tiny fraction are the institutions of learning that manage to gather the best brains among both its teachers and students, give them stimulus and opportunity, but do not guide them too rigidly, do not overeducate them.

A research center, however, is not such an institution. A few of its members are first class, but the rest are composed of whoever happens to be available at the institution that got the center grant, rather than being recruited from among the best in the field around the country. One might argue that the opposite would be undemocratic, elitist. May be. But the price is inefficiency in the use of public funds allotted to research, which damages everybody.

Other old but newly fashionable tendencies with the same end result are various concepts of socialism in research and egalitarianisms of various sorts.

Example to Avoid

To illustrate some of the aforementioned counterproductive policies and practices, it might be more instructive to conclude with one example to avoid rather than one to follow. Traveling abroad, one can find many university departments or institutes renowned because of the results of a few outstanding members of the institute. However, even in advanced democratic countries, one is often surprised by the inefficiency seen—manifested, for example, by the unexpectedly large staff of the institute, distinctly larger than that of a typical institute of comparable output in the U.S. One wonders what it must cost to fund these institutes.

Let us sketch the atmosphere in such an institute. First one notes that the working hours seem to be interpreted by most of the research staff as the upper (rather than lower) bound on the hours one should actually work. The institute is deserted after five o'clock (which might not be a problem if the research staff worked at home, but that does not seem to be the case). Trying to be there in the evening, or on a Saturday or Sunday, requires some determination and courage. One has to wander through unlit corridors and grope in the dark for the light switches and keyholes. There are scheduled work breaks in the morning and afternoon, but these are regularly extended to hour-long coffee or tea sessions with a lively chat, only rarely concerned with research. These sessions are defended by the need to discuss departmental problems. Some of the research staff even have a breakfast session immediately after arriving—late—to work. Of course, the few productive and renowned members of the department are not frequently seen at these sessions; but no one finds it wise to boycott them completely. He would miss the gossip or be accused of not playing with the team.

None of this seems to matter in this institute, since the funds come from the government more or less automatically. The institute director, a hard-working man with a solid international reputation, sees the problem, of course. But he is unable to remedy it, for it originates from the socialist system pervading the universities and governmental institutions, which is in striking contrast to the country's efficient private industry. The professor-director cannot change the salaries of his research assistants, secretary, or technician. He cannot fire them, even if they do next to nothing. His assistant can work on his doctorate for five, or even ten years, displaying curiously little interest in finishing (his salary is not too bad and, of course, secure). The secretary, chronically ill with a tennis elbow, pursues lengthy cures in a spa. In the meantime, the professor is left with no secretarial assistance at all. Every petty problem must be decided by meetings of the employees. The labor union dominates, but seems interested mainly in the well-being of its local members, and not in the productivity which affects the well-being of the country as a whole.

Research institutes like that are affordable only by countries that have already become rich as a result of thriving private enterprise. But even if they are an affordable luxury, they do non-negligible damage the country's economy and lower the living standard. Obviously any changes that might be made in the system of research and graduate education in the U.S. should prevent situations such as that depicted in this example. Following the aforementioned principles ought to ensure that.

Conclusion

The principles enunciated here are fair. They stimulate and motivate researchers by giving them the maximum possible freedom. They reward researchers by exploiting free market ideas. They have been proven to be more effective than other systems.

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