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Viewpoint

Consumer preferences and funding priorities in scientific research

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Current debate in much science policy is primarily over research priorities. It generally assumes continuation of the present general system for funding that research. However, this system has the defect of tending to centralize the decisions concerning research priorities and the future of specific researchers and research groups.

This paper proposes a more de-centralized market-oriented funding system, in which the use of research papers is monitored, and researchers receive a form of royalty on each such use. The tax-payer would still pay for research, but not until after it started to produce results which were used. A greatly improved form of monitoring citations might provide the measure of usage. Some implications of usage-based funding are considered.

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BASIC SCIENTIFIC RESEARCH has long been considered essential to increases in economic productivity: advance of knowledge is thought to account for as much as two-thirds of long-term growth in output per worker.[1] Different kinds of knowledge, however, are not equally valuable. Therefore, given scarce resources, research directions must be prioritized.

In many sectors of our economy, scarce resources are allocated relatively efficiently and optimally through a competitive free market. Often, resources will only be allocated at all, however, if rights to the resulting products (including patents, trade marks, and so on) can be defined and enforced at reasonable cost. Since the product of scientific research is intellectual property, the rights to which are often difficult to enforce, a free-market economy will not effectively allocate resources to scientific research, much less correctly prioritize research directions.[2]

These and other considerations have led to the view, especially since Vannevar Bush's influential report in 1945,[3] that basic scientific research requires the financial support of the public sector, even in an otherwise predominantly free-market economy. I accept this view, but not that which usually accompanies it: that such research also requires to be directed by the public sector.

Experience has shown that central direction of an economy is neither efficient nor optimal. Central direction cannot incorporate, as can decentralized markets, "the knowledge of particular circumstances widely dispersed amongst thousands or millions of individuals".[4] In perhaps no sector is this more true than in basic science, which depends on the specialized talents, quirks and resources of tens of thousands

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of individual researchers. Therefore, I argue that basic science *cannot* be efficiently centrally directed, and that current debate within the scientific community over basic research priorities is, from an economics point of view, fundamentally unresolvable.

However, I also argue that debate over research priorities under central direction is of second-order importance. Of far greater potential importance is debate over whether there exist alternative funding strategies which substitute market-oriented, decentralized decision-making in place of central direction.

This article considers (1) a hypothetical free market for scientific research, (2) the nature of the present market failure, and (3) possible funding strategies which circumvent that failure.

I argue that a 'consumption-funded' or 'usage-funded' strategy is superior to the current 'investment-funded' strategy, in that funding priorities could be more market-determined by decentralized consumer preferences. Such a usage-funded strategy, however, requires a method of keeping track of the usage made of past research to all currently active scientists.

My intention is to spark debate over such a method, since any form of consumption-funded strategy, much less a practical implementation, has hardly been explored.

A hypothetical free market

Let us start by examining what the market for scientific understanding would be in a 'perfect' capitalist economy. In such a hypothetical economy, new scientific knowledge would not be free, but would be exchanged for a price. Its quantity (and quality) would be governed by supply and demand. Everything else being equal, increased demand for scientific knowledge by consumers would initially raise its price, stimulating more research. Increased supply would lower its price, reducing incentive for research.

Efficiency in such a market would result from the self-interest of its three important participants: investors, producers and consumers. Investors would risk their capital on the production of scientific research in order to earn profits (assuming that to be their main goal – for the moment). Producers, or scientists, would perform research for salary compensation (again, taking that to be their main goal). Their product would be scientific knowledge, which they would sell at the prevailing market price. Consumers would purchase scientific knowledge to further their own scientific, technological, or cultural purposes. In a sense, through those purchasing decisions, users would both privately fund and privately direct basic science.

Individuals would, of course, play more than one role in the market at any given time. For example, (entrepreneurial) scientists might finance the production of their own research, even as they use the results of other scientists' research. Indeed, in the short to medium term, the dominant users of scientific understanding would be (and are) other scientists. Therefore, the relative activity levels of different areas of research would be determined mainly by the 'collective' judgement of all the individual researchers making up the scientific community.

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Note that, in such a free market, scientific knowledge would have no 'intrinsic' value. Its price (and a measure of its economic value) would not be determined directly by "the extent that they reveal the laws and interactions governing ... phenomena", or by any of the other idealistic criteria of scientific worth that have been proposed.[5] Indeed, I agree with those who accept that there is no absolute standard by which a scientific result can be evaluated. Just as other commodities, such as fine art, or automobiles, scientific understanding has value that can only be measured through market exchanges between producers and users.

Market failure

A central difficulty with scientific research, of course, is that a true market does not exist for it, as one does for other goods and services. Successful science requires a system of more-or-less unhindered communication — or, at least, fewer hindrances than is compatible with allowing non-leaking transfers from supplier to user. New scientific results cannot easily be purchased without uncontrolled dissemination to a larger, non-paying community.

It is difficult to assign and enforce ownership of the results of scientific research. Without such property rights, there is little incentive for private investors to fund basic research, despite its sometimes high eventual value to the community at large. (This discussion ignores the role of private philanthropic sponsors, which is not usually great in terms of the total, and private research funded by companies in their own laboratories.)

Other considerations include the possible riskiness of research (results may not be satisfactory), and the long-term nature of much basic research. Additionally, research is often undertaken by people whose other activities (such as teaching) are not seen by them as part of a market system (even if university administrators and others are more aware of the market context). Because of such market failures,

optimal production of scientific research (quantity, quality or area) will not occur without public sector funding. The question we ask here is: what funding strategy would be most efficient? To answer it, I distinguish two general funding strategies.

In the first, funding occurs at the investor/producer interface (the 'investment' strategy). The public sector acts as a surrogate investor, funding research that otherwise would not be produced. This structure requires a high degree of concentration of the administration and general control of research, since consumers or users, who ordinarily direct the supply of many other goods and services, are not naturally included.

In the second, funding occurs at the producer/consumer interface (the 'usage' strategy). The public sector pays for research as and when it is used by those (mainly other scientists) who have no mechanism by which to pay. This structure can be privately directed, as it attempts to fund according to the way users would have funded, had a free market existed.

Investment-funded strategy

Current public-sector intervention is dominated by the investment strategy. Scientists are directly supported by a government agency to produce research results. The difficulty with this strategy is that users (as a whole) do not fund research, and so their preferences, dispersed amongst a perhaps nebulous, world-wide community of research scientists, are replaced by those of administrators and advisors to government agencies. The best such agencies can do to help them direct basic science is to try to guess consumer preferences. The natural result is the so-called 'peer review' system, in which a small fraction of expert scientists are asked for their preferences.

Whilst peer review is better than nothing, it is unlikely to be a perfect surrogate for the actual usage of research. There is, of course, no direct evidence available on how good a surrogate it is, but evidence from other areas shows consumers often behaving differently from what was expected. Many new products are commercial failures, although developed, designed and marketed by professionals.[6]

Indeed, there are reasons to expect that the current peer review system is less accurate at guessing the preferences of the community of working scientists than even a simple random poll of working scientists. For instance, guessing consumer preferences may not be their main objective in practice; it is quality, relevance, timeliness, and so on, which they tend to focus on. In my view these are not the prime issues. Moreover, the peer review system is currently dominated by scientists with established reputations. From one theory of human capital,[7] the value of these scientists decreases whenever new research results are accepted which represent departures from the prevailing world-view.[8] Therefore, one might expect a bias against radically new science under the current system. The history of professions which are controlled (from within) by the current elite is one in which progress is impeded, rather than furthered.

Within this centrally-funded and centrally-directed organizational structure, non-economic criteria inevitably enter into the funding process. Pork-barrel politics, a subject of contemporary debate, is difficult to avoid. The choice of which broad areas of research to fund are especially likely to be influenced by political considerations. Research on superconductitivity, less funded in the early 1980s, suddenly becomes perhaps overfunded in the late 1980s, diverting support from scientists working in other areas.

Usage-based strategy

In the usage-based strategy the public sector acts as the bill-payer, paying for research as and when it is used by those who have no mechanism by which to pay. Research would still be centrally-funded, but not be centrally-directed.

I emphasize that, as noted above, the dominant users of basic research results are other scientists working in related areas, in the immediate and longer-term future. Some research results are used mainly by, for instance, government departments who initiated the work and paid for it: I am excluding such cases here, since they reveal a current situation where the user is paying directly (and perhaps fully) for the research which was wanted by that user.

The value of a research result lies principally in whether it is used by scientists. Therefore, as each scientist uses another's research result during the course of performing research, the public sector would 'reward' the original researcher. Past research results that are used often by current scientists would be rewarded heavily; results that are not used would not be rewarded.

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Prerequisites

The principal prerequisite for a usage-based strategy to funding scientific research is the development of a

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measure of the usage of past research results by current users (taken to be other scientists). Such a measure would reflect the *current* importance of a particular piece of *past* research, and would allow the public sector to compensate producers of much-used past research.

Operationally, one might imagine dividing the total public-sector budget for basic research amongst every piece of past research, weighted according to that measure. In other words, every piece of past research would receive a form of royalties according to how much it was used during the current year.

Since scientific production and usage is principally mediated by journal publications, past research might best be identified with past publications. Clearly, defects in the publishing system would need remedying, and the role of conference papers, and the like would need taking into account.

Let us assume this can be done, and (for present purposes) count conference papers as journal publications. Then, every previous publication would receive royalties according to how much it was used during the current year.[9] Independent scientists would keep their royalties, with a percentage going also to investors.

In practice, most scientists might, in exchange for salary, sign away much of their research royalty rights to the scientific research corporations for which they work. The royalties collected by these corporations, after subtracting operating expenses, would then be the profit to the investors in the corporation.

Insofar as past research is identified with past publications, it is natural to use some variant of science citation indices to measure the usefulness of those past publications. Insofar as these indices have defects in this application, they should be improved.

Science citation indices, pioneered commercially by Garfield in the early 1950s,[10] list, for each previously published scientific article covered by the index, articles in the current year that cited it as a bibliographic reference. Thus they could measure consumer preference, if their limitations were surmounted. They have become standard bibliographic tools for studying the relative quality of research (and researchers);[11] they incorporate the judgements, interests and circumstances of a wider range of people than peer reviews probably do.

Perhaps the most important imperfection in citation indices is the current lack of incentives for citation practices to be uniform. Most scientists have, over the years, developed their own individual citation practices, often based on very different criteria. It would probably be necessary to develop new guidelines, or rules of citation, to which scientists would be expected to conform if they wished to be funded. Indeed, one purpose of this article is to spark interest in developing such guidelines. Citation practice need not be fixed according to current custom.

These rules of citation would be aimed at providing incentives to prevent scientists, intentionally or not, either underciting or overciting the work of others. For example, to minimize underciting, some formalized system of complaint is likely to be necessary, in which those owning rights to a particular article can 'file suit' against others for inadequate citing (although careful attention would need to be paid to the procedure, to avoid an expensive, legal jungle). As with patent protection, citation protection might best be policed by the concerned parties themselves. Routine complaints might even be arbitrated by peer review panels, agreed to in advance upon submission of articles.

To minimize overciting, it might help if authors themselves distinguished between two kinds of citations: bibliographic type B citations, which serve mainly to guide the reader to a more extensive literature, and incorporated type I citations, to work which was actually used and incorporated into the current work. Only the type I citations would be used in measuring the impact of a previous piece of research. Like some other features of my proposed scheme, this would require the co-operation of the journal publishing industry.

Citation indices themselves would need improvement. Many journals are not covered. The usual emphasis is on English language writing. Should book reviews and similar material be included? Might late inclusion of a December issue of a journal (perhaps because of late publication) cost an author a 12 month delay in payment? How to handle authors with the same name, or authors who change names or initials, or whose names are misquoted by the citing author? Current indices are inadequate for assessing royalties.

Is equal weight to be given to each type I citation (those that would count when assessing royalites)? Perhaps authors might be asked to assign fractional weights to each article they cite, to sum to unity. As a concrete example, I indicate in the reference section of this article which citations are of type B and which are type I, and the fractional usage of the type Is.

The scheme could be elaborated so that some royalty accrued to authors further up the line. If Smith cites Jones, and Jones drew on Baum, then Baum's royalties should reflect Smith's indirect use of his work. The royalty administrators might also be able to allow for Baum's use of Zabrinski (say), a third-order citation.

The total for a publication might be some weighted sum of the primary, secondary, ..., order uses.

With usage-based funding, scientists who cannot attract corporate investment, but have resources and belief in themselves, could gamble and eventually be compensated if they produce work cited by others

Advantages

Let us assume that a satisfactory measure of usefulness is evolved and made available. We can then consider some advantages of the proposed manner of funding research.

First, basic science would no longer be as centrally directed as it is at present, but instead be directed by at least the bulk of working scientists. If the free play of market forces can generally enhance the level of economic efficiency, then there should be such an enhancement here.

Second, I believe the bureaucracy and overheads required to administer the current system would be greatly diminished. Much of the not-inconsiderable time and effort spent by working scientists on preparing research proposals to (and evaluating research proposals for) government agencies would be spent doing research instead.

Third, any favoring of any specific type of researcher (older, male researchers, for instance) would be the result of market forces rather than of tradition, political pressure, and so on.

Fourth, entrepreneurial science currently exists only on a relatively small scale. With usage-based funding, scientists who cannot attract corporate investment, but who have resources and belief in themselves, could gamble and eventually be compensated if they produce work which is cited by others. At present, no mechanism exists for providing such compensation (patents, for instance, not being applicable to most scientific research, as distinct from technological).[12]

Citations-based funding might encourage scientists to publish as many papers as possible, in the hope of maximizing the number of citations they then receive. However, I see the possibility that the number of publications will decrease. At present, many scientists have an incentive to publish as much as possible; in a citations-based reward system, the incentive would be to maximize the number of citations received.

This would encourage a focus on high quality papers, because uncited papers would bring little benefit to the scientist. If journals were to receive some share of the royalties accruing to their authors (I acknowledge this is to raise a host of other, controversial issues), then their refereeing systems might become yet stricter.

Finally, the way researchers are organized would be likely to change greatly because of the way funding would come after, not before, undertaking research, and the way final funding of any given research would not be guaranteed. Whether this shift would be towards small entrepreneurial groups, or large corporations, or in any other direction, I will not speculate.

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See text to understand why each reference in this paper ends with a B or an I.

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9. As with all human knowledge, scientific information must in the long term be considered common property. After some limiting time, private ownership to the rights to such royalties would terminate, along with the royalty payment itself. Perhaps, as with patents, that limiting time would be 17 years or, as with copyright, 28 years.
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