SOCIOLOGY OF SCIENCE

"Undemocracy": inequalities in science

Inequality, an intrinsic feature of science, has trended upward in recent years

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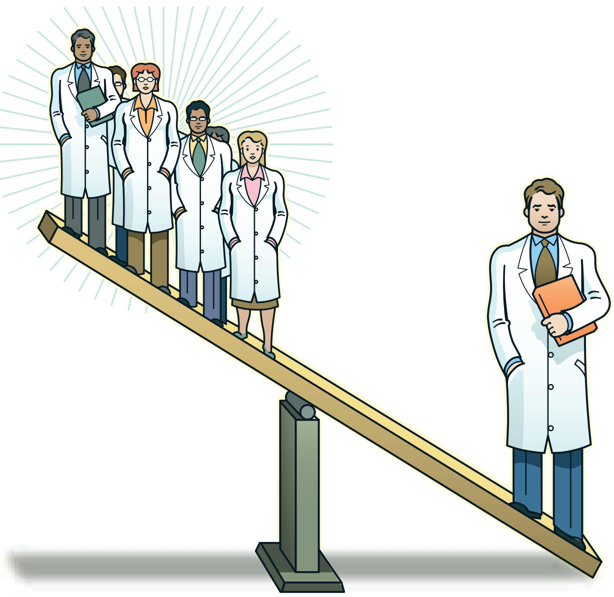

In recent years, academic scholarship and public discourse have become increasingly preoccupied with social and economic inequality, which has risen in many countries. It is surprising that more attention has not been paid to the large, changing inequalities in the world of scientific research. I suggest that although the basic structure of inequalities in science has remained unchanged, their intensities and mechanisms may have been altered by recent forces of globalization and internet technology.

POLICY

By "inequalities," I mean differences in three major domains: resources, research outcomes, and monetary or nonmonetary rewards. At times, my discussion is conceptual and somewhat speculative, as precise and meaningful measurement of these outcomes is difficult. Even though I refer primarily to basic, natural science, most of my general conclusions are also applicable to the social and applied sciences.

AN INTRINSIC PROPERTY OF SCIENCE. Derek Price observed in 1963 that inequality in science is inherently high and called it "undemocracy" (*1*), meaning that a great scientist's value for science far exceeds that of ordinary scientists. Scientific outputs and rewards are much more unequally distributed than other well-being outcomes, such as education, earnings, or health (*1*, *2*).

One source of inequality in science is what Robert Merton called the "Matthew effect" (*3*), referring to Matthew 25:29 in the Christian Bible: "For to all those who have, more will be given, and they will have an abundance; but from those who have nothing, even what they have will be taken away." This "rich get richer" effect means that eminent scientists receive disproportionately greater recognition and rewards than lesser-known scientists for comparable contributions. As a result, a talented few can parlay early successes into resources for future successes, accumulating advantages over time.

Although science rewards all participants through a skewed tier system with the most substantial rewards going to the top performers in a tournament-like reward system, science has attributes that resemble a "winner-takes-all" market: high visibility of top winners, a large contestant base, accumulation of advantages, absence of physical or cultural boundaries, and intense competition (*3*, *4*). Thus, many scientists feel that merely being good at their jobs is not enough. Competition is all about priority, a scientist's claim to be the first to make a big discovery (*5*, *6*).

Whatever their cause, high inequality in scientific rewards is often defended on two grounds. First, given the positive externalities of science (*7*), the more skewed rewards are, the greater the incentive for outstanding scientific work that will ultimately benefit all of humanity (*8*, *9*). Second, as a profession, science is supposed to practice what Merton called universalism (*10*), a norm that dictates that evaluation in science be based solely on merit rather than on functionally irrelevant factors such as gender, race, nationality, age, religion, and class (*2*, *10*). This merit-based system makes inequality seem fair and acceptable.

Before the 19th century, science was mainly a small-scale, personal pursuit enjoyed by a few leisure-class amateurs. Over the next two centuries, it expanded enormously into an institution characterized by certain distinctive features: a huge, well-paid, professional workforce; large-scale government and industrial support; reliance on the university as institution; graduate student labor; and a peer-review system of evaluation (*7*). Advances in Internet technology have facilitated the rapid, broad dissemination of research results (*11*).

Although these features have made scientific production faster and more voluminous, they have also rendered the evaluation of scientists less substance-specific and more "numbers-based." Scientists are increasingly likely to be judged by whatever numbers they can generate in terms of publications, citations, research grants, prestigious awards, research team size, and memberships in elite academies than by their actual scientific contributions (*7*). This tendency may have been amplified by increasing specialization, such that scientists in one specialty area find it difficult to understand content in another. University administrators, faced with uncertainties and competing demands for scarce resources, have strong incentives to use externally generated and validated indicators (*12*).

HAS INEQUALITY IN SCIENCE INCREASED? More empirical research is needed to answer this question, but I believe that two trends have caused inequality in science to rise over time. First, growth in high rewards in science has been limited, occurring much more slowly than the expansion of science itself. It is well known that the number of Nobel Prizes is fixed, although many Nobel Prizes in natural science have been shared in recent decades [see supplementary materials (SM)]. Although the number of academically appointed scientists with Ph.D.'s increased by 150% between 1973 and 2010 in the United States, the number of newly elected mem-

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bers each year to the National Academy of Sciences covering all scientific fields stayed at 60 for a long time until it finally went to 72 in 2001 (see SM).

Given science's concentration of high rewards to a select few, the large increase in the population of scientists (*7*) means a higher concentration over time. Furthermore, the tendency toward numbers-based evaluations has made it possible for an outsider—either a scientist in a different field or a nonscientist, who nonetheless may be in position to distribute resources—to pass judgment on any scientist, thus providing an easy pathway for the Matthew effect.

As with income inequality in the United States in general, inequality in academics' salaries has trended upward, both between private and public universities and among universities of each type (*13*). For individual academic scientists, salary inequality has increased substantially since the 1970s, across all ranks and diverse fields (*14*).

Here are two examples of intensified inequality in science today. First, many new science Ph.D. recipients from American universities in recent years have been unable to obtain regular academic positions and instead are taking postdoctoral fellowships or other forms of non–tenure-track employment (*7*). One source of this problem may be the large supply of well-trained foreign students and immigrant scientists (*7*). Of course, the system of postdocs and temporary employees provides benefits to both senior and junior (dependent) scientists. However, the former benefit more, as they are given more credit due to the Matthew effect.

Second, Internet technology, a globalized economy, inexpensive air transportation, and relatively peaceful world politics have created an unprecedentedly interconnected world (*15*). In this new global environment, a successful scientist filled with ideas at a prestigious university in America or Europe can design studies and have them carried out by dependent collaborators in less-developed countries, such as China, where labor-intensive scientific work can be conducted at lower costs. Such collaborations are complementary and can lead to mutual benefits (*16*); at the same time, they amplify inequality across individual scientists. Although global collaboration likely benefits all scientists, benefits vary with a scientist's position in a collaboration network. More-successful scientists are much more likely than less-successful ones to be centrally located in global collaborative networks.

CONTEXTUAL SOURCES OF INEQUALITY. The importance of institutional environment to scientists is well documented (*2*, *17*, *18*). Scientists affiliated with prestigious

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institutions are more productive and better rewarded than those who are not. Hence, greater institution-level inequality serves to intensify the individual-level inequality of scientists.

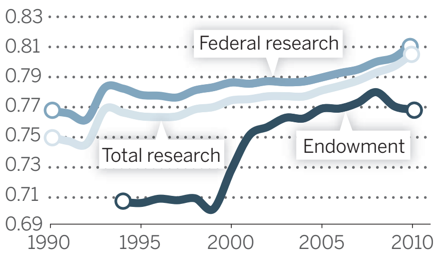
There is some evidence that institution-level inequality in resources has increased over time. Institutional inequalities are shown in the chart by using the Gini coefficient, which ranges from 0 for absolute equality, to 1 for absolute inequality (see the chart). Despite already high levels of inequality in three resource measures, the Gini coefficients trended upward during the period. Part of the reason for the increases was an expansion in institutions that participate in research. If we restrict our analysis to a limited set of universities that have always been active in research, there is no clear trend (see SM).

Large country-level differences in scientific activities have long been noted (*19*). Historically, the world center of science has shifted several times; in the past nine decades, America has dominated (*7*). However, just as between-country income inequality has narrowed in the world, mostly because of a rise of income in China (*20*), between-country differences in science have also narrowed, thanks to the globalization of science (*7*, *16*).

Globalization of science and the increasing use of Internet technology have conflicting effects on inequality in science. At the levels of individual scientist and institution, they have tended to intensify inequality. At the country level, they have narrowed it. However, the most significant consequences of these two forces for science have been positive overall: the large expansion of science as a collective enterprise and the resulting rapid progress of science on a global scale (*16*). In the long run, resources and rewards must be allocated so that inequality, although incentivizing scientists to make important scientific discoveries, is properly managed and controlled. Especially important is the need to invest sufficient resources in young scientists before they gain recognition. ■

Inequalities in U.S. universities' research funding

Gini coefficient



RESOURCE INEQUALITY. Gini for resource inequality across U.S. universities, 1900–2010. Data reflect total research expenditure, federal research expenditure, and endowment for U.S. universities. Data from Center for Measuring University Performance, which draws from National Science Foundation (research expenditures) and National Association of College and University Business Officers (endowments). (See SM.)

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SUPPLEMENTARY MATERIALS

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