MAXIMIZING QUALITY AND VALUE-RETURNS FROM PUBLIC INVESTMENTS IN SCIENCE: LESSONS FROM THE HISTORY OF MEDICAL AND AGRICULTURAL RESEARCH

by

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The scientific research system in the United States is one of the most productive in the world. In recent decades, it has evolved under the philosophical foundation Vannevar Bush espoused 50 years ago in *Science: The Endless Frontier* (Bush, 1945). Bush believed that science could be used to "insure our health, prosperity, and security as a nation in the modern world." In pursuit of these ideals, since 1945, the United States has invested more of its wealth in scientific research and related higher education than any other nation of the world, though not always as the highest percentage of gross domestic product.

In this country and abroad, there are three broad domains in which the power of science is harnessed for the benefit of society -- one is in medicine, the second is in engineering, the third is in agriculture. Few would argue that the United States is not a leading nation in medical research and technology, in agricultural research and technology, and in science-based military technology. In spite of our successes in science and education, as The Honorable George Brown pointed out in the *Report of the Task Force on the Health of Research* (Brown, 1992):

> "Today, however, the United States faces wide-ranging societal crises and challenges, in our educational system, our environment, our manufacturing sector, our health care system, our inner cities, our financial institutions, and even our system of government. This paradox -- growing knowledge, accompanied by growing societal crisis -- implies a complex, nonlinear relationship between advances in knowledge and advances in society. More specifically, it suggests either that we are not adequately using the knowledge we already have, or that we are not sufficiently producing the knowledge we actually need. Of course, both of these conditions may be partly true. "

As we reflected on Congressman Brown's concerns we were keenly aware of the following precepts of science and technology as they pertain to the "social contract" between science and society that is implicit in the philosophy Vannevar Bush espoused:

> Science is the discovery of new knowledge through research. Scientific inquiry is driven mainly by the curiosity and enthusiasm of individual and groups of scientists. Basic research is inquiry aimed at understanding the physical, biological, social, and mathematical world around us. Applied research is inquiry aimed at discovering useful guidelines for management of the natural resources, business enterprises, social and governmental institutions, and the health, agricultural, environmental, educational, recreational, and other services needed by society. Science provides the power to understand both natural and social phenomena, and by virtue of that power, to expand the range of choices for management of nature and human institutions.

Technology is the art of making things useful. Technological innovation provides the means by which the power of science can be harnessed to drive the economic systems of society by providing new products, processes, and services that are needed by society.

But science and technology alone can not provide the wisdom to make wise choices. Wisdom derives not only from science but also from the humanities. For this reason, the power of scientific and technological innovation must be balanced and focused for the benefit of society by reflective study of philosophy, justice, aesthetics, history, religious faith, and all the pain and suffering as well as the joys and satisfactions of individuals and groups within society.

The discussions in this essay focus on two of the three domains in which science is harnessed for the benefit of society -- medicine and agriculture. Both biomedical and agricultural research have contributed greatly to human understanding of the causes and cures for disease and to the production and marketing of food. But we were astonished to discover that the United States is distinguished as a nation in two remarkably dissimilar ways in medicine and agriculture:

The US health care system is by far the *most costly* in the developed world and the cost of food and fiber products delivered to American households is the *least costly* of any developed nation of the world (Becker, 1992; OECD, 1990; World Bank, 1991; Korb and Cochrane, 1989; NIH, 1991)!

Our objective in this essay is to explore certain aspects of the history of agricultural and medical science research and to present some preliminary observations and hypotheses about the comparative costs, influences on science quality, and magnitude of returns to society from these alternative methods by which decisions are made about public investments in science. From an admittedly less-than-exhaustive analysis of the performance of the research systems of medicine and agriculture and the health-delivery and food-delivery systems of our country, we offer three hypotheses for further discussion and perhaps spirited debate:

1) Evolution of the methods of funding scientific research in medicine and in agriculture, coupled with the types of research that are undertaken in each field, are an important part of the reason for the remarkable contrast in the relative cost of medical care and the cost of food and fiber in our country.

2) Systems of decision making that maximize the quality of scientific research provide little or no assurance of an optimum (or even near optimum) value-return from public investments in science, at least in the short term.

3) Agriculture and medicine can learn at least a few lessons from each other about how to maximize the quality of science and value-returns from public investments in both fields.

In searching for possible, probable, (or at least partial!) explanations of these widely divergent national outcomes, we recognized several important facts and distinctions:

1) The objectives of medical science research and agricultural research are quite different. The medical sciences have focused mainly on understanding disease in humans and using this knowledge to cure those who are sick. By contrast, agricultural research has focused mainly on understanding how crops grow and using this knowledge to feed a hungry population of humans.

2) Understanding disease in humans and understanding how crops grow are only a part of the larger challenges of delivering quality medical services and wholesome food to consumers. Thus, biomedical research is only part of the total medical research enterprise just as crop production research is only a part of the total agricultural research enterprise of our country.

3) The agricultural and medical research enterprises of the United States are extraordinarily productive. As a result, the quality of our best health care and food products and services is exceptionally high.

4) The results of publicly funded agricultural and biomedical research in the US are published in literature that is freely available in every country of the world.

5) The results of American biomedical and health-care research are used mainly by licensed health-care providers who help individual patients recover from disease or injury. In agriculture, the results of research are used mainly by non-licensed food and fiber producers and distributors who help feed and clothe a growing population of consumers in the US and abroad.

6) Both in the US and other developed countries, payments for medical-care products and services are made mainly by third-party payers -- commercial or tax-supported insurance and various types of health maintenance organizations. By contrast, payments for food and fiber products and services generally are negotiated directly by cost-conscious consumers and/or distributors.

7) Some of the differences in per-capita and/or total costs of health care and food products and services probably can be attributed to some social ills within American society -- poverty, inadequate education, injury-inducing violence, lack of prenatal care, voluntary and involuntary risk-increasing life style choices, and some fraud, waste, and abuse.

But we were further astonished to discover the extent to which certain aspects of the methods of decision making about public investments in scientific research in medical and agriculture research are contributing to the remarkable differences in costs, benefits, and value-returns from these research investments.

Two methods are commonly used in making decisions about public investments in scientific research -- scientific-merit focused competitive funding and administratively focused formula funding. Scientific-merit focused competitive funding is the dominant method for decision making in the medical sciences (Chubin and Hackett, 1990; King and Rimkunas, 1991a,b; NIH, 1992; Strickland, 1974, 1989; Harden and Rodriques, 1993). Administratively focused formula funding is the dominant method for making decisions in the agricultural sciences (Krugman and Cowling, 1983; NRC, 1989, 1990; Ruttan, 1982a,b; USDA, 1987). The goal of this essay is to compare and contrast the costs, influences on science quality, and magnitude of returns to society from these alternative methods by which decisions are made about public investments in science.

<u>HISTORY OF PUBLIC-SECTOR INVESTMENTS IN SCIENCE</u>

During most of the history of science, science was pursued by amateurs rather than by professionals -- people who were naturally curious about the nature of things and the way they function. There were few if any jobs as scientists because science was done mainly as a hobby -- by clerics such as Mendell, teachers such as Newton, or by indentured employees such as Linaeus in the early phases of his career. All of these persons pursued their scientific curiosity while supporting themselves in other ways or by indenturing themselves to wealthy patrons of science. “These amateurs had no fear of perishing for lack of publication because they enjoyed permanent tenure in the institution of their own curiosity” (Horsfall and Cowling, 1976).

Using tax revenues to support scientific research is a relatively recent innovation. This novel idea was first tried in Germany in 1852. It was so successful that the idea quickly spread to other countries and later to other fields of science and technology including medicine.

History of Publicly funded Agricultural Research

In 1852, the province of Saxony made the first public investment in scientific research. They created at Giessen a new kind of institution -- a Landwirtshaft Versuchsstation (Agricultural Experiment Station) where the taxpayers hired professional scientists to pursue their curiosity about crop production at the experiment station. The results were presented to the local farmers and merchants who produced the improved crops and sold the derived products to the people who were also the citizens who paid the taxes that paid the bills at the experiment station. It was a brilliant idea which has paid off handsomely. This idea has spread all over the world (Horsfall and Cowling, 1976; National Research Council, 1987).

In the United States, the Morrill (Land Grant College) Act of 1862 recognized the importance of publicly supported agricultural research and education, and the desirable linkage between the two, by setting aside federal land in each state for use in developing colleges of agriculture and mechanical arts (hence the name "A & M"). Twenty-five years later, the Hatch Act of 1887 created the State Agricultural Experiment Stations which were established in connection with most of the agricultural colleges.

Today, among the federal agencies engaged in basic and applied research, the U.S. Department of Agriculture ranks sixth. In addition, some agriculturally relevant research is done under competitive grants administered by the National Science Foundation, the Department of Energy, the National Aeronautics and Space Administration, and a few other federal agencies. But even with this relatively low ranking of federal support, public support of agricultural research in this country is larger than private investment in agricultural research (National Research Council, 1990).

In 1992, the last year for which reliable statistics are available, $7.7 billion was expended in agricultural research and outreach activities. The distribution was as follows -- about $3.8 billion (49 percent) from the private sector and about $3.9 billion (51 percent) from the public sector. Within the public sector, this total of $3.9 billion was almost equally split between federal sources and state and county governments and other public nonfederal sources. During the past decade the percentage of private funding for agriculture research has grown while the percentage of public funding has decreased (i.e., in 1986, the percentages were 44 percent and 56 percent, respectively).

History of Publicly Funded Medical Research

Medical education and research in the United States evolved in a very different way --in large part from philanthropic contributions by a number of wealthy and socially enlightened families, such as the Rockefellers and Carnegies, who led to establishment of the first medical research institutions around the turn of the century (Mider, 1976; Harden, 1986). It appears that the scientific challenges addressed by these privately funded research institutions were not driven by society's health needs as a whole, but rather by the curiosity of the founders themselves, or selected advisors who had an interest in specific types of disease problems. The need to select among alternative possibilities for research efforts in these institutions led to some of the earliest systems of "peer reviewing" of proposals for medical research.

The first public investments in medical science research in the United States were made when Congress provided funds for the establishment of a Laboratory of Hygiene in 1887 and a Marine Hospital Service in 1889. Personnel of these organizations pursued research on cholera, leprosy, malaria, syphilis, gonorrhea, pneumonia, and other infectious diseases and quarantines of concern to both military and civilian health authorities. The Public Health Service (PHS) was formed in 1912 and in 1918 established the precedent of using funds appropriated by Congress to make grants for scientific research purposes.

In 1930, the Ransdell Act redesignated the Laboratory of Hygiene as the National Institutes of Health (NIH). The Public Health Service Act of 1944 provided greater authority for the National Institutes of Health to conduct biomedical research. The need for more effective treatments for wounds during World War II, the development of sulfa drugs, and Fleming's discovery of antibiotics provided major impetus for improved biomedical research during the period immediately following World War II. This remarkable success story in the medical sciences was part of the background that led Vannevar Bush to prepare his now-famous report to President Truman, *Science: The Endless Frontier* (Bush 1945).

As a result of the Public Health Service Act, in 1946 NIH established the Office of Research Grants. The entrepreneurial spirit of this office, and the substantial confidence of the Congress in the public benefits that would flow from the science funded through that office, led NIH and the PHS to become the largest agencies in the federal government in terms of dollars expended for basic and applied research. For more than two decades now, the National Institutes of Health have distributed about three-fourths of their total appropriations in the form of competitively awarded research grants. This system of competitive grants has made NIH the most respected medical research establishment in the world (Harden, 1986; Strickland, 1989).

In 1991, the total investment in research activities for medical science was approximately $13.4 billion (52 percent) from the private sector and approximately $12.4 billion (48 percent) from the public sector. Within the public sector, this $12.4 billion was split approximately $10.6 billion (86 percent) from the federal government and about $1.8 billion (14 percent) from state and local governments (NIH, 1994). As with agriculture, the percentage of private funding has been increasing in recent years (i.e., 49 percent private and 51 percent public in 1989).

COMPARATIVE IMPORTANCE OF AGRICULTURE AND MEDICINE IN AMERICAN SOCIETY

In 1989, the total expenditures for food products and related services was about $448 billion, or about 9 percent of our gross domestic product. Total expenditures for medical services and health-care products were similarly large -- in 1989, about $604 billion or about 12 percent of our gross domestic product (OECD, 1991; World Bank, 1991; U.S. Department of Commerce, 1992). Thus, both agriculture and medicine have been, are now, and always will be large parts of our national economy. However, as we are all aware from the current debates in Washington, the cost of health care is increasing at a much greater rate than probably any other segment of our economy.

DOMINANT THEMES OF AGRICULTURAL AND MEDICAL SCIENCE RESEARCH

Within the agricultural sciences, the dominant theme has been “production agriculture.” This theme led to studies of the production, processing, marketing, and consumption of food, feed, fiber, timber, and ornamental crops, animal husbandry, soil science and agronomy, horticulture, agricultural and forest economics, processing and preservation of meat, poultry, and dairy products, forest and natural resource management including range, livestock, wildlife, and fisheries management, wood and paper science and technology, home economics, and rural sociology.

These various areas of emphasis developed as scientific subdisciplines within the general field of agricultural and natural resources sciences. The resulting research has been oriented mainly to understanding how crops grow and using this knowledge to deliver wholesome food, feed, and useful fiber products to consumers at reasonable cost. In recent years, increasing attention has been given to environmental consequences of intensive farming, nutritional values of food, integrated management of pests and diseases, and agribusiness interests.

In the medical sciences, "biomedical research" has been the dominant theme. Strong emphasis has been given to studies of the etiology and pathology of infectious disease, development of diagnostic tools and procedures, discovery and development of medicines, antibiotics, and therapeutic and rehabilitation services to help individuals recover from disease or injury, development of surgical tools and procedures, replacement organs, and medical prostheses. Many different medical specialties have evolved within the medical sciences including internal medicine, pharmacology, psychotherapy, neurosurgery, dentistry, ophthalmology, orthopedics, chiropracty, physical therapy, etc.

The resulting biomedical science research has been oriented mostly toward understanding disease processes and developing diagnostic tools, pharmaceutical products, and surgical procedures that can help patients recover from disease or injury. In recent years, increased attention has been given to dietary influences on health, and disease and accident prevention in populations as opposed to individuals. Biomedical research has never included serious concern about the economics of health care and health-care services.

DECISION MAKING ABOUT AGRICULTURAL AND MEDICAL SCIENCE RESEARCH

Private Sector

Both commercial profits and public benefits are to be derived from pursuing agricultural and medical research. For this reason, it should be no surprise that both private firms and government organizations contribute substantially to the total investment in scientific research in the agricultural and medical sciences. In the private sector, both in agricultural and medical research, decisions about alternative opportunities for investments in research are made by intellectual and managerial leaders hired by the company. Decisions are made primarily on the basis of the likelihood of developing a commercially successful product or service. This means that the research must be of sufficiently high quality and applied focus to provide the foundation for reliable decisions about both the effectiveness of the products and services being developed and their potential for commercialization. Often this research comes under the watchful eye of the U.S. Food and Drug Administration (Bell, Clark, and Ruttan, 1994).

Public Sector

As indicated earlier, public support of agricultural research provided a little more than half (51 percent) of the total of $7.7 billion spent in 1992, while public support of medical sciences research was a lower percentage (48 percent) of the $25.8 billion spent in 1991. However, the public sector investments in agricultural research are not dominated by the federal government. Federal government spending was approximately equal to other public support for agriculture, but was 86 percent of the total public spending for the medical sciences.

In the public sector, decisions about alternative opportunities for investments in research are made in two very different ways. Peer-reviewed competitive funding is the dominant method for making decisions about alternative research ideas in the medical sciences. By contrast, formula funding is the dominant method for making decision in the agricultural sciences. It is not so much that specific decisions are made by formula, but that the formula directs the money towards what are considered economically important areas. Furthermore, there is often a requirement for matching agricultural research funding.

Agriculture

Most of the federal portion of public funding for agricultural research is provided by the U.S. Department of Agriculture. The USDA employs scientists as in-house researchers in regional and national laboratories such as those at Beltsville, MD, and Peoria, IL, and as cooperative research faculty at the land-grant universities. In addition, federal funding for agricultural research is provided through cooperative arrangements with state agricultural experiment stations operated by the land-grant universities.

Tax revenues provided by Congress, state legislatures, and county commissioners are combined according to formulas that specify minimum matching requirements (hence the term "formula funding"). Promising areas of scientific endeavor are identified by individual scientists, scientific teams of various types, and research and administrative leaders in the U.S. Department of Agriculture, 56 state agricultural and 8 regional forest experiment stations, and 60 land-grant universities. Federal and state university scientists are selected to develop science projects that fit their personal and professional research interests, and also fit with research and technology development priorities established by mutual agreement among federal, regional, state, and county authorities; commodity group representatives; and agribusiness interests. This "federal-state-county-agribusiness partnership system" has produced an extraordinarily broad, scientifically based agricultural research and educational system that is unmatched in any other nation of the world (USDA, 1987; NRC, 1989). While competitive grants have been given for agricultural research, the total amount of competitively awarded research funding is less than 10 percent of the total public support. Furthermore, it might be stated that the formula funded research has been oriented toward process innovations, which tend to lower costs, as opposed to product innovations, which can tend to raise costs.

As with the use of any public funds, from time to time questions have been raised about the mechanisms of public support to agricultural research. These questions have been raised by members of Congress; science administrators within federal, state, and private research organizations; and various other critics of the scientific research establishments of our society. These questions have led to sometimes heated debates between severe critics and staunch defenders of the system.

Bredahl, Brant, and Ruttan (1980) have provided a thoughtful analysis of the comparative behavior and productivity implications of administratively focused formula versus competitive grants systems of decision making. They conclude that:

> "In our view, the current argument about the merits of institutional and [competitive grants based] project research support more appropriately is cast in terms of the relative mix of the two systems of support than in the absolute merits of either system. We do, however, insist that the issue of efficiency in the allocation and use of research resources is important. The productivity of agricultural research judging from historical rates of return has been high. This places a heavy burden on those who would argue for the shift of resources from institutional to project support to demonstrate that such a shift would either enhance the productivity of the existing level of research support or draw substantial new resources into the agricultural research system."

Krugman and Cowling (1983) addressed the issue also:

> "[Administratively focused formula] funding is sometimes considered an anathema to progress, and competitive grants as the "only way" to ensure adequate quality and innovation in scientific research. This debate rages on, radiating much heat but shedding little light on the real difficulties of both systems. In our view, most of the failings of formula funding (weak scientists carrying on unending tests of unimaginative hypotheses) are consequences of inattentive or spineless administrators who want "peace at any price" and lack the courage necessary to purge the institution of scientists who are not advancing the frontiers. By the same token, many truly imaginative research ideas are rejected by some reviewers of competitive grants because the reviewers themselves lack the imagination to recognize an innovative proposal. …We believe that a mixture of both types of support is desirable: [administratively focused formula] funding to provide reasonable stability, especially for long-term experiments, must be coupled with the flexibility to pursue imaginative ideas [that] require a renewed investment. Greater firmness in administering formula funds and longer time frames for competitive grants would do much to increase the value of both systems."

Medicine

Most of the funding for medical sciences research is provided through NIH. While each of the institutes maintains a sizable in-house staff of research scientists, a large portion of NIH funds is used to support extramural research. Peer-reviewed competitive funding mechanisms are used almost exclusively in the distribution of these extramural funds. Over the past 30 years, the NIH has honed these competitive methods of decision making to a fine art. Approximately three-fourths of NIH funds are distributed to individual investigators (or small teams of investigators) who submit proposals for research in areas of science which they themselves believe to be very promising. These "individual investigator initiated" or "unsolicited proposals" are evaluated for scientific merit by peer panels. A smaller fraction of NIH funds is distributed in response to proposals solicited in specific areas of the medical sciences. In these cases, promising areas of scientific endeavor are identified by administrative authorities within NIH and requests for specifically targeted proposals are issued.

Both "unsolicited proposals" and specifically targeted proposals are submitted to panels of peer scientists. Proposals are evaluated on the basis of the quality of hypotheses, methods, facilities, and past performance of individuals or groups of investigators. Relevancy to the specific program needs within one or more of the institutes also is considered in making award decisions. Generally, however, scientific merit is weighted more heavily than program relevance. This scientific merit focused competitive system has produced an extraordinarily broad medical research and educational system that is unmatched in any other nation of the world (Mider, 1976; Strickland, 1974, 1989).

As with agricultural science research, from time to time questions are raised about the peer review systems. Members of Congress, scientists (especially those whose proposals are not funded), and various other critics of the scientific research establishment of our society often enter into heated debate about the system with staunch supporters (Strickland, 1974, 1989; Harden and Rodriques, 1993). Chubin and Hackett (1990) have provided what appears to be the most thorough scholarly analysis of the use of peer review. They conclude that although the systems used at NIH and in various other granting agencies all have some faults, and modest changes would lead to improvement, no general acceptable alternative has yet been devised that would not have a larger array of faults.

TRANSLATION OF SCIENTIFIC FINDINGS FROM AGRICULTURAL AND MEDICAL SCIENCE RESEARCH INTO USEFUL PRODUCTS AND SERVICES

In agriculture, translation of discoveries in science into reliable processes for production, processing, and delivery of wholesome food, feed, and fiber products and services is accomplished by a diverse array of mostly non-licensed professionals. They include agricultural research scientists, regional and county extension agents, nutritionists, dietitians, private practitioners, consultants, sales agents, food and fiber production and processing industries, farmers, foresters, field laborers, wholesalers, retailers, restaurant owners and service personnel, family members, and many others.

In the agricultural sciences, these knowledge-delivery steps have been an integral part of the research and outreach system from the very beginning of public investments. The economics of agricultural production, and comparative costs of alternative systems for delivering food and fiber products and services, also have been an integral part of the agricultural research and extension system from the beginning.

In medicine, translation of discoveries in medical science research into reliable diagnostic and medical-treatment products and services is accomplished by an elite corps of mostly licensed health-care professionals. They include medical research scientists, physicians, physician assistants, nurses, nurse practitioners, dentists, dental hygienists, dental assistants, pharmacists, physical therapists, nutritionists, paramedics, dietitians, private practitioners and consultants, pharmaceutical and health-product manufacturers and sales agents, private and public hospitals and clinics, employees of public and private health insurance and health management organizations, county and municipal health officials, state boards of health and social services, family members, and many others.

In recent years, the medical research system of the US has given more substantial attention to translation of discoveries in the medical sciences into practical guidelines for keeping people healthy. But these technology-transfer functions have been much less well integrated into the fabric of the medical-science and health-delivery establishments of this country. The economics of medical practices and the comparative costs of alternative systems by which to prevent or cure different types of health problems have not been important objects of medical science research. Greater attention usually has been given to practices and procedures by which physicians can help patients *recover from disease after they have become ill* rather than to practices and procedures by which society can *prevent disease occurrences* and help individuals avoid conditions that are hazardous to their health.

COMPARATIVE QUALITY OF RESEARCH AND VALUE-RETURNS FROM INVESTMENTS IN THE AGRICULTURAL AND MEDICAL SCIENCES

We were disappointed to learn that there have been no direct comparisons of the quality of research in the agricultural and medical sciences, nor have objective methods been developed by which to compare the results of research in these two fields. We were pleased to discover, however, that sector-wide analyses have been completed in the agricultural sciences. They show annual rates of return between 50 and 120 percent in many countries of the world (Ruttan 1982). Regrettably, however, we could find no comparable sector-wide analyses of rates of return on investments in the medical sciences in any country of the world

It is widely assumed, however, that the quality of medical science research in the US is generally very high. This assumption is based in part on the fact that most investigators in the medical sciences have had to meet a double standard of peer review -- one before the research is funded and the other in getting the research published in refereed journals. However, the cost of medical services in the United States is also very high. In fact, *Americans pay a higher percentage of their gross domestic product for health care services than many other developed nation of the world* (11.8 percent in the United States, compared to 8.7 percent in Canada, 8.2 percent in Germany, 6.7 percent in Japan, and 5.8 percent in the United Kingdom).

The quality of agricultural science research in the US is generally very good, but is not so highly respected as in the medical sciences. However, the cost of food and fiber products in the United States is remarkably low. *Americans pay a lower percentage of their gross domestic product for food and fiber products than any other developed society in the world* (8.7 percent in the United States, compared to 9.4 percent in Canada, 11.8 percent in Germany, 11.5 percent in Japan, and 12.9 percent in the United Kingdom).

While neither the quality of research nor the method of funding can be directly attributable to the amount of money spent on the resulting products, we believe that these comparisons are very interesting.

COMPARISON OF AGRICULTURAL AND MEDICAL ECONOMICS

While developing this essay, we were also astonished to discover another remarkable difference between agricultural and medical sciences. Agricultural economics appears to be a well-developed scientific discipline but medical economics appears to be a relatively less well-developed scientific discipline.

In the United States, tenured faculty in agricultural economics have been maintained in essentially all colleges of agriculture since the early part of this century. Courses and graduate degrees in agricultural economics are offered in about 60 universities in the US. The Economics Research Service has been an important research unit within USDA since the 1930s. Currently, about 4,000 professionals consider themselves agricultural economists. The American Agricultural Economics Association and its regional affiliates currently publish six different refereed journals dealing with contemporary issues in national and regional agricultural economics.

By contrast, courses in medical economics are available in some (but not all) colleges of medicine and schools of public health. We have yet to find even a single university that has a department of medical or health economics or that offers graduate or undergraduate degrees in medical or health economics. Health economics research and education generally is pursued by economists who have elected the health-care arena as their particular sphere of economic interest. Most academic specialists in health economics are appointed in departments of economics -- mainly within schools of business management or colleges of arts and sciences rather than within colleges of medicine or schools of public health.

At present, there are only about 300 to 400 professionals who call themselves medical or health economists. Until very recently, there were no professional societies of either medical or health economics. Furthermore, there are only two regularly published journals (*Health Economics* and *Health Affairs*), both of which are published by profit-making corporations rather than professional societies.

Thus, it appears that about 4,000 professionals in the US derive their livelihood from scholarly analysis of how this country uses about 9 percent of its gross domestic product in feeding itself. By contrast, it appears that only about 300 to 400 professionals derive their livelihood from scholarly analysis of how this country uses about 12-14 percent of its gross domestic product in health care.

When James Wyngaarden, former Director of NIH, was asked for his opinion about this difference, he responded:

> "Agriculture was always a free-market competitive enterprise in which prices for purchases of food and fiber products and services were negotiated openly and directly between purchaser and various alternative suppliers. Thus, there was always a substantial need for professionals who would study the market forces involved and make recommendations to keep costs of food products and services low. By contrast, medical costs have rarely if ever been negotiated in the United States. Persons who were ill did not shop around for low-priced medical products or services; they were sick, needed help to get well, and were glad to pay whatever it cost to get the best products and services available. Until very recently, cost containment was simply not an issue in medicine. Thus, there was no need for professional economists to study the (almost nonexistent) market forces involved and to make recommendations about alternative systems of health care."

In a recent article in *Daedalus*, the journal of the American Academy of Arts and Sciences, William Richardson, President of Johns Hopkins University stated:

> "A pronounced slowdown in federal research dollars and reimbursements for clinical practice is part of general retrenchment, but also a reflection of failures to address societal concerns. …Indeed it is possible that the various constraints of the new era will compel academic health centers to do the right things, albeit for previously unanticipated reasons, such as 1) a more appropriate balance between primary care and specialization; 2) greater responsiveness to the needs of the community, including preventive care as applied to populations rather than in the hospital; and 3) a conscientious outreach to and integration with other academic departments and divisions within the home university. …We will still be regarded as the pacesetters of the world in biomedical research and education. And, like those corporations that have survived the near melt-downs of the late 1980s and early 1990s, we will be poised for more rapid and balanced growth once the inevitable recovery comes."

When we inquired more deeply into these matters we gradually learned that a series of near-simultaneous events during the 1940s served, from that time forward, to insulate the rapidly expanding biomedical sciences from the realities of health care economics. The Public Health Service Act of 1944 provided greater authority for the National Institutes of Health to conduct biomedical research. The need for more effective treatments for wounds during World War II, development of sulfa drugs, and Fleming's discovery of antibiotics provided major impetus for improved biomedical research during the period after World War II. This remarkable success story in the medical sciences was part of the background that led Vannevar Bush to prepare his now-famous report to President Truman in 1945 -- *Science: The Endless Frontier*.

About this same time (1947), the first private insurance system was developed to help individuals and their employers pay the costs of medical services. Later, in 1965, the federal government established Medicare and Medicaid to help pay the costs of medical care services for some elderly and lower income persons. The generosity of these "third party payers" for medical services decreased the motivation for doing research on the cost-effectiveness of various medical and surgical procedures, practices, and health-care systems. Thus, sustained funding for development and adoption of high-cost medical technologies, coupled with continuing lack of funding for comparative health-outcomes and health-economics research, contributed to the current rapid rise in the cost of medical-care and health-care services in the US (Cutler 1995, NIH 1995).

RELATIVE STRENGTHS AND LIMITATIONS OF AGRICULTURAL VERSUS MEDICAL SCIENCE RESEARCH: A COMPARATIVE-OUTCOMES ANALYSIS

From three life-times of observation of the medical and agricultural research establishments in the US, and the history of these enterprises here and in a few other countries, we developed the following comparative-outcomes analysis of these two sectors of American society:

In one sector, **agriculture**, now commanding about 9 percent of the total US economy,
-- after about 130 years of experience,
-- using a highly-evolved, formula-based, curiosity- and relevancy-driven, but administratively-focused, highly consultative county-state-federal, university, agribusiness, partnership-system of decision making about funding for projects and programs of publicly supported agricultural research,
-- which we have applied in
  -- all 50 states of a very large nation,
  -- with very abundant natural and energy resources, and
  -- large regional differences in climate, soils, and available water supplies,
-- with a strong and sustained focus on
  -- outreach and extension activities,
  -- preserving the family farm,
  -- maximizing production of marketable food and fiber crops and derived products,
  -- optimizing economic benefits and minimizing costs to the individual and society as a whole, and
  -- educating a well-qualified but largely non-licensed population of professionals,
-- but with less concern about
  -- sustainability of agricultural and forest ecosystems,
  -- conservation of soil resources,
  -- optimum use of available water supplies,
  -- safety of food supplies, and
  -- optimum management of forest, wildlife, wetland, and rangeland resources,
-- we have succeeded in
  -- ***developing a very good quality of agricultural science research,***
  -- ***feeding, clothing, and sheltering a large, diverse, and growing human population***,
-- and we have done so
  <u>at lower per capita cost than in any other developed nation in the world</u>.

In another sector, **medicine**, now commanding about 12-14 percent of our total economy,
-- after about 50 years of experience,
-- using a highly-evolved, scientific-merit focused, curiosity-driven, largely federal-government financed and operated, competitive-grants system of decision making about funding for projects and programs of publicly funded biomedical research,
-- which we have applied in the interest of serving the health needs
  -- of a large human population,
  -- in a very large nation,
  -- with substantial diversity in ethnic, racial, social, economic, and life-style make-up,
-- with a strong and sustained focus on
  -- maximizing quality in the biomedical sciences, and
  -- sustaining human life by
    -- discovering the causes and developing cures for infectious disease,
    -- developing vaccines to prevent the development of disease,
    -- developing reliable diagnostic tests and procedures,
    -- developing replacement organs and medical prostheses,

-- educating an elite corps of licensed physicians and certified health professionals,

-- but with less concern about

-- outreach and technology-transfer activities,

-- prevention of disease in populations,

-- minimizing costs and optimizing social and economic benefits either for the individual or society as a whole,

-- providing universal access to health care services,

-- we have succeeded in

-- ***producing the highest quality of medical science research and medical education***,

-- ***developing the highest quality of disease-diagnostic services in the world today***,

-- but we have done so

-- ***at higher per capita cost***, and

-- *with less-than-desirable general availability of medical services than many other developed nations of the world*.

CONCLUSIONS AND RECOMMENDATIONS

From this admittedly very brief (and undoubtedly incomplete) outcomes-based analysis of these two systems of decision making in science, we offer a few conclusions and recommendations which we believe will enhance both the quality of science in agriculture and medicine, and the value-returns to society from its investments in these (and other) fields of science and engineering:

1) Competitive peer-review mechanisms for decisions about scientific research contribute to the quality of science. We believe this is true both in the agricultural sciences and in the medical sciences.

2) As shown by the comparisons developed in this essay, competitive peer-review mechanisms for decisions about alternative investments in scientific research provide no assurance that an optimal or even near-optimal value return will be derived by society from that investment. Translation and transfer of discoveries in science into useful, cost-effective, and readily available information about alternative practices, products, and services also are essential.

3) The agricultural sciences can learn a valuable and important lesson from the medical sciences by investing a larger proportion of their resources in competitive grants which are open to all the creative minds that can be attracted to the intellectual problems of agriculture and natural resource management.

4) The medical sciences can learn a valuable lesson from the agricultural sciences by:
   a) enlarging the consultative roles played by nurses, pharmacists, municipal and state public health officials, and leaders in health maintenance and health insurance organizations in helping establishing priorities for medical science research,
   b) giving increased attention to research aimed at optimizing the costs of health-care services both to individuals and to society as a whole, and
   c) investing a larger proportion of their resources in extension, outreach, public-education, and technology-transfer activities.

5) Greater attention also should be given to development of: a) university-based and NIH-based programs of graduate education and research in health economics, and b) national and regional associations of health economics professionals. It is not clear that it will be

necessary to develop departments of health economics within colleges of medicine and schools of public health. But much stronger ties are needed between health economics researchers (in whatever academic units and other organizations they serve) and: a) faculty members and students within colleges of medicine and schools of public health, b) biomedical research scientists and leaders in NIH, c) academic medical research centers, d) state, regional, county, and municipal boards of health, e) health maintenance organizations, and f) health insurance organizations. It may even be worthwhile to consider establishment of a National Institute of Health Economics Research and Education.

In these latter two connections, we applaud the recent decision of NIH to sponsor an <u>NIH Economics Roundtable on Biomedical Research</u>. The charge to members of the Roundtable was to:

> "identify optimal analytical approaches and the data and methodology needed for the development of an ongoing, effective research benefits assessment program that would assist the NIH to:
>
> - evaluate the contributions of biomedical research in extending life and reducing the burden of illness and disability and its impact on health care costs;
> - demonstrate the effect of publicly funded research on [medical education and] training, and on the performance of research universities, pharmaceutical firms, and related industries in developing new products and services; and,
> - identify the value of spin-offs from biotechnology and biomedical research that are applied in other industries.

Finally, we believe that the quality of science and value-returns from public investments in the medical sciences, agricultural sciences, and other fields of science and engineering will be enhanced if more scientists and engineers in these fields will recognize the wisdom in Sterling Hendricks's (11972) assertion:

"<u>The opportunity to inquire into the nature of things is a rare privilege granted to a few [scientists among them!] by a permissive society</u>."

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