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Drawing the Line: The Role of Government in Agricultural Research

John M. Antle

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Objective Analysis
for Informed
Decision Making

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1. Introduction and Overview of Conclusions

The growth and success of publicly funded agricultural research -- including the land grant system in the United States, the large national agricultural research systems in countries such as Australia and Brazil, and the system of international agricultural research centers -- is well documented and widely acknowledged (Ruttan (1982), Anderson *et al.* (1988), Alston, Norton and Pardey (1995), Huffman and Evenson (1993)). Yet it is also clear from recent events that the level of public support for agricultural research is decreasing, and the rationale for and direction of these institutions is being questioned in various countries (e.g., see the recent report by the National Research Council in the United States (1996), the Industry Commission report in Australia (1995)). The declining real level of governmental support for publicly funded agricultural research has led to various proposals for alternative means of support, including greater reliance on competitive grants to allocate national funds rather than block grants, joint public/private research ventures and privatization of extension programs (Huffman and Just (1994), Tisdell (1996), Dinar (1996)).

The goal of this paper is to consider the appropriate role of government in agricultural research. I draw from relevant developments in economic theory as well as the well-known and now extensive agricultural economics literature on the rationale for and returns to investment in agricultural research (Alston, Norton and Pardey provide a comprehensive overview of this literature). I begin by considering the broader question of the appropriate role for government in the provision of intellectual property, of which agricultural research is one important special case. Combining that material with the prevailing understanding of the economics of the innovation process, I conclude that there remains an important but changing role for government support of agricultural research. The appropriate role for government must be considered in relation to a variety of issues, principal ones being: institutional arrangements for the definition and protection of intellectual property at both the national and international levels; the regulation of related products and processes; the state of scientific and technological advance; and society's needs and values.

Based on currently available data, it is difficult to say whether or not the overall level of government support of agricultural research is too large or too small. The evidence on investment in conventional product-related research suggests that there is under investment, although there are also reasons to believe that these estimates of returns on research investment may be overstated. But there are no such data on returns to basic research, policy research, or other information provided by public agricultural research institutions such as market price forecasts. It is possible to say, however, that the amount of publicly funded research going to traditional plant breeding and other product-related research and extension is probably too high *relative* to the amount that goes into other types of research that are not related to commercial products. In addition to basic disciplinary scientific research, publicly supported research institutions are probably under investing in interdisciplinary, policy-oriented and problem-solving research that is important to efficient policy and regulatory design for the provision of environmental quality, protection of public health, and other public goods. This line of reasoning also suggests that there is probably an under investment in the collection and dissemination of various types of information and other knowledge-based products that are largely public goods.

The implications of my analysis for the role of government in agricultural research are somewhat different for the lower-income countries. In many countries, legal and other institutions do not operate to effectively define and protect intellectual property rights and to finance private research and development. Economies of scale in the production of research discoveries also may be an impediment to private research, as well as capital market imperfections. Under these conditions, government funding of research may be warranted as a second-best solution, even though public research institutions may themselves be inefficient producers of research and technological innovations.

The question of where to draw the line between public and private research and extension is one part of the issue of the government's role in agricultural research. But there is a broad array of research ranging from basic science to policy research and policy-relevant science -- including research in such areas as food safety, nutrition, environmental sciences, social sciences and economics -- where the products of research are relatively pure public goods. Consequently, there is little or no private sector investment in these fields because commercial products are not and never will be produced. For this type of research, the relevant issue is not where to draw the line between private and public research, rather the relevant issue is determining the efficient level of public investment. Because it is difficult to quantify the benefits of research that produces pure public goods, it is difficult to determine the social rate of return on these investments, and thus difficult to determine the appropriate level of public sector investment. Within a system in which publicly funded research depends on the political process, the public sector may either over- or under invest in these types of research depending on the strength of various advocacy groups. As governments move towards systems that base research funding on benefit-cost analyses, there is a risk that there will be a bias against basic research and policy research because of the difficulty of quantifying the benefits of public goods.

2. Some Relevant Facts

It will be useful to begin with some data that will enable us to put the discussion of intellectual property rights and agricultural research on a factual basis.

Figures 1 and 2 show how the global investment in agricultural research changed from the 1960s to the 1980s. In 1980 dollars, the total investment increased almost three-fold, from $3.36 billion in 1961-65, to over $9 billion in 1981-85. The share of the less-developed countries in the earlier period was 39 percent, and that share increased to about 48% in twenty years. Thus, in real terms, the investment in agricultural research world wide increased rapidly over this period, and increased at a higher rate in the less-developed countries, on average.

Figure 3 shows agricultural research expenditures for regions of the world in relation to agricultural GDP. The more-developed countries increased their agricultural research expenditures from about 1 percent of GDP to about 2 percent. In the less-developed countries, these shares are generally less than 1 percent, increasing on average from about .24 percent in 1961-65 to about .41 percent twenty years later. Combined with the data from the previous two figures, we can see that while agricultural research investment increased much in the less-developed countries, these countries still invest much less than the higher-income countries, and the rate of growth has not kept up with the growth in the rest of their economies.
A key issue to be discussed later in this paper is the definition and protection of intellectual property rights. Figure 4 shows data from the United States for annual issues of intellectual property rights for new plants and plant varieties. Plant patents and plant variety protection certificates both increased progressively since 1970. Utility patents covering genetically altered plants have increased since the mid-1980s. Both of these facts reflect the progressive increase in the protection of these forms of intellectual property rights in the United States.

Closely related to the trends in protection of intellectual property rights is the overall trend in private and public expenditures on agricultural research in the United States. Since 1980 real public expenditures have increased little, whereas private research expenditures have continued to increase along the same trend line since the early 1960s.

Another important difference between private and public agricultural research is the type of research that is done. Figure 6 shows that in the United States, public research is split about equally between basic and applied, with little investment in developmental (that is, for product development and commercialization). In contrast, the private sector does much more developmental and much less basic research.
Another view of private research is found in Figure 7 which shows the break down of private research by areas. In 1960, most private research was in food products and farm machinery. By 1992, farm chemicals had become the largest share, and farm machinery declined substantially. Importantly, the figure does not contain a category for policy research, environmental research, or other research activities that we will describe below as public goods.

3. Agricultural Research and Intellectual Property Rights

I begin with a discussion of the fundamental questions that arise in the analysis of the production of any form of intellectual property in society, including all types of basic and applied research. The basic theoretical issue is whether intellectual property rights can be defined and protected. As established rigorously by Arrow and Debreu in the 1950s, a competitive market economy with well-defined and protected property rights will achieve an efficient allocation of resources and maximize social welfare for a given distribution of asset ownership in the economy. Note that within this welfare economics approach to the issue, the *appropriate level of government intervention* is defined as the one that maximizes aggregate social welfare typically measured in terms of aggregate income (or more precisely, in terms of aggregate consumer and producer surplus).

Under these idealized conditions, economic theory indicates that the role of government should be limited to defining and protecting property rights. There is no need for the public provision of intellectual property when such property can be defined and protected like other forms of physical property. Markets will exist for intellectual property, just as they exist for other forms of productive capital.

Of course, in most cases intellectual property rights are not easily defined or protected because intellectual property tends to have the characteristics of a public good. The Arrow-Debreu theory then implies that a market economy will fail to efficiently allocate resources. In particular, the market economy will not provide adequate incentives for private individuals to produce some types of intellectual property. The economics literature provides several solutions to this problem. One solution is to devise policies that will create incentives for private provision of a public good such as research. Another solution is to create property rights through a patent system. A third solution is for the government to produce the public good. In this section we consider each of these approaches and describe the advantages and disadvantages of each.

3.1 Schultz's Model: Public Goods and Economies of Scale

Nobel Laureate Theodore W. Schultz laid the intellectual foundations for the public funding of agricultural research, and by implication, for the public provision of any intellectual property that has similar properties. In his landmark 1964 treatise, *Transforming Traditional Agriculture*, he presents two fundamental reasons why a competitive, market-based economy will not provide the socially optimal level of agricultural research.

First, Schultz argues that research is a *pure public good*, i.e., research is a good that is both *nonrival* and *nonexcludable* in consumption. Research is the creation of knowledge, and knowledge can be utilized by various entities in society without preventing others from utilizing it, thus research is a good that is nonrival in consumption. Moreover, once an idea is disseminated, the discoverer or inventor of the idea cannot exclude others from knowing it and using it, thus research is nonexcludable. These two attributes mean that the discoverer or inventor of new knowledge does not have well-defined property rights to his or her knowledge, and private markets therefore will not exist for such goods. This in turn means that, by definition, markets will not provide incentives for resources to be allocated to the production of research and its dissemination, even though society would attach a positive value to such research.

Second, Schultz argues that the production of scientific research is different than the production of some kinds of knowledge and intellectual property. Whereas an individual artist or musician might be able to produce intellectual property efficiently, individual farmers cannot afford to produce the scientific knowledge needed to increase agricultural productivity beyond relatively low levels. Successful experimentation and related scientific activities are much more effective when undertaken at scales unattainable by individual farmers. This was true 50 or 100 years ago when agricultural science relied largely on application of classical plant and animal breeding, and is even more true today as agricultural science increasingly resorts to "big science" in the form of highly advanced cellular and molecular biology for plant and animal breeding, and advanced biochemistry for related chemical innovations.

Closely related to the economy of scale argument are other important features of research that disfavor private investment. One factor is the long gestation period for an invention, estimated to be from 10 to 30 years. Another factor is the high degree of uncertainty associated with agricultural research such as variety improvement, and the effect that uncertainty has in combination with imperfect capital markets on the willingness of the private sector to undertake such investments. An additional important factor in countries such as the United States is the costs associated with the regulation of foods and food-producing technologies such as pesticides and genetically engineered plants and animals. The high costs of the regulatory process are likely to bias the innovation process towards larger firms and thus implicitly discourage the overall level of inventive activity (Ollinger and Fernandez-Cornejo, 1995).

An important caveat must be mentioned in relation to Schultz's arguments for the under-provision of agricultural research in a market economy. As we will discuss below, there are important areas of invention where the public good and economy of scale arguments are of limited relevance. First, most mechanical and chemical inventions can be patented, thus transforming the public good into a *club good*, i.e., a good for which consumption is nonrival but excludable. Second, agribusiness firms that produce mechanical and chemical inventions do achieve a high degree of specialization and a large scale of production sufficient to support substantial levels of investment in research and development. Indeed, in some countries such as the United States, private research investment is larger than public research investment, although the emphasis in private research is more toward product development and less in basic and applied research than is the case with publicly funded research (Fuglie *et al.*, 1996).

In conclusion, Schultz applied the basic Arrow-Debreu analysis of market failure in general equilibrium to the case of agricultural research. It is important to note, however, that even though this analysis implies that a market economy will underproduce a public good such as agricultural research, it does not necessarily follow that the best policy to address this market failure is for the government to produce the public good.

3.2 The Efficient Provision of Public Goods

Paul Samuelson established in a 1954 article that the efficient provision of a public good is defined as the quantity satisfying the condition that the sum of all individuals' marginal willingnesses-to-pay equals the marginal cost of providing the good. In terms of conventional demand and supply curves, the demand curve for a public good is obtained by summing the individual demand curves *vertically*, to reflect the fact that any given quantity of the public good can be consumed jointly by everyone.

The key policy problem with public goods is to determine how much should be provided to achieve the greatest social welfare, that is, how to determine the efficient allocation of resources to the provision of a public good. One solution is to simply ask everyone to reveal their marginal willingness to pay for a public good. Then the government could tax them accordingly and use the tax revenues to provide the public good itself or to contract with a private firm to produce it. The difficulty with this solution, of course, is the free rider problem: individuals will not reveal their true marginal willingness to pay because they can consume the public good without paying for it.

Using taxes to pay for a public good raises the question of what tax rates are needed to finance the efficient provision of the good. The solution to this problem can be shown to require that each individual pay a marginal tax (or price) equal to his marginal willingness to pay (these are known as Lindahl prices or taxes). Again, the problem is reduced to the need to know an individual's value of the public good. The economics literature has provided a solution to the problem of how individuals can be induced to truthfully reveal their willingness to pay for public goods, known as the Groves-Clarke mechanism. These mechanisms involve providing individuals side-payments that are functions of the values that other individuals claim for the public good (Varian, 1992).

Even though it is possible, in theory, to devise a mechanism to induce individuals to reveal their willingness to pay, and it is possible in theory to use this information to design an efficient allocation of resources for the provision of public goods, important problems remain. One is the practical political problem of implementing this kind of policy. Is it politically feasible or practical to design a system that involves different taxes for each kind of public good? In addition, these simple theoretical analyses assume away important knowledge and information problems. And also very importantly, these analyses presume that once the efficient amount of a public good is known, the government will then find an efficient way for it to be provided.

Before proceeding, it is worth mentioning that another solution to the public good problem is to have citizens vote to decide how much of a public good to produce. Under a well-defined set of conditions, it can be shown that a majority voting system is not likely to result in the efficient provision of a public good. The problem with voting schemes is that they lead to the allocation being determined by the preferences of the median voter. This allocation is not likely to correspond to the efficient one, and can result in either too much or too little of the public good being provided (Mueller, 1989).

3.3 Patents, Contracts, Club Goods, and Monopoly Power

Another way for government to try to induce an efficient production of intellectual property is to create institutions and laws to protect intellectual property. One mechanism to achieve this result is the awarding of a property right to the research discoveries, or providing prizes for research discoveries. The patent law system, such as the one established by the Patent Act of 1790 in the United States, is one way that property rights to research discoveries can be defined and protected. In the case of conventional process inventions for manufacturing, or for consumer goods, the patent system provides a way for inventors to define their intellectual property by obtaining a patent for a period of 17 years, and a legal system through which this property can then be protected by suing for patent infringement.

When inventions can be patented, then instead of a pure public good we have the case of a public good that has the characteristics of nonrival consumption, but excludability by virtue of the patent right. Public goods with these characteristics are referred to in the economics literature as *club goods*. The creation of club goods through the patent system addresses the market failure that occurs because of the lack of property rights, but creates another market failure by assigning monopoly rights to the invention. Thus, the introduction of patents reduces the social losses associated with the under provision of research, but in its place creates a market failure through the restriction of the use of the research discoveries through the granting of monopoly power (Wright, 1983).

Despite the distortions implied by monopoly rights, patents should lead to higher social welfare than the situation where there would be little or no inventive activity. The provision of the public good, even at a monopoly price, generates net benefits to society. However, because a monopolist charges a higher price than average cost of production, a monopoly results in a higher price and a lower level of consumption of the goods produced by the invention, and thus a lower level of social welfare, than would be the case if the patent-protected goods were sold at a competitive price. A monopoly right also implies a different distribution of benefits from the invention than would be the case if it were priced at average cost, another important factor to be considered in public policy.

The length of the patent right can be varied to balance the tradeoff between social costs associated with under provision of research effort and the restriction on its use associated with monopoly patent rights (Nordhaus, 1969). Although a patent's life is typically limited to fixed number of years, with rapid technological innovation patents are likely to create a monopoly right for the useful life of the invention. It is unlikely that a patent system will be able to be designed where the length of the patent can be varied to efficiently limit the degree of monopoly power afforded by the patent.

Patents for Biological Inventions

Many agricultural innovations are embodied in plants or animals and this fact has impeded their development in the private sector. When an invention is embodied in a plant or animal, the sale of the product transfers the capacity to reproduce it without any knowledge of how the invention was created. So except in the case of hybrid seed which cannot be used to reproduce itself effectively, protection of the invention is virtually impossible without patents or similar types of property rights. But until recently biological inventions were considered "products of nature" and thus not patentable in the United States and other countries.

U.S. patent law was amended in 1930 by the Plant Patent Act to provide patent protection to asexually reproduced plants. While this law aided protection of tree crops and ornamentals that can reproduced through cuttings, it did not protect crops grown from seed. Sexually reproduced seed crops were protected by the 1970 Plant Variety Protection Act. Plant breeders are awarded certificates for distinct new varieties that provide property rights for 17 years. These certificates are administered by the Department of Agriculture, whereas plant patents are administered by the Department of Commerce's Patent and Trademark Office. In 1994 the Plant Variety Protection Act was strengthened and made to conform with international standards for plant breeders' rights established by the International Union for the Protection of New Varieties of Plants. Also a U.S. Supreme Court ruling in 1980 determined that living material is patentable. Later in the 1980s court rulings and Patent Office decisions led to patents being issued for genetically engineered plants and non-human animals. These patents provide broader property rights than plant variety certificates, as they may apply to traits that can be expressed in multiple species. In addition, scientists conducting research supported by Federal funds are allowed to file patents for their inventions since 1980. Universities may also own patents, and may license inventions to private firms for commercialization. These developments provide greater economic incentives for investment in research and commercialization efforts. But scientists also express concerns that the development of broad property rights may impede basic and applied research.

3.4 Public Provision of Public Goods as a Second-Best Policy

Another way that government can play a role in the provision of a public good such as agricultural research is to produce the good itself. Government support of agricultural research is widespread. Most governments support some form of publicly funded agricultural research. Whereas private research is more important, in dollar terms, than publicly funded research in some countries such as the United States, in many countries most agricultural research is government sponsored. Brazil provides an example of this situation, where it is estimated that the private sector provides less than 10 percent of total agricultural research investment. There are various explanations for this situation, a point to which we shall return at the end of this paper.

Governments can organize their own research laboratories or contract research work with private firms. In either case, the government is essentially issuing contracts for a defined amount of research activity. The disadvantage of this type of contract is that it provides less incentive for research productivity, unless the contract's provisions can be related to success in the same way that a prize or patent would. A key problem is that the researchers typically have much better information about the probability of research success than the research administrator who awards the contract. A related problem is that it may be costly for research administrators to monitor the level of work effort in a contractual scheme, a situation familiar to anyone who has worked for a research organization.

The inefficiency of centralized systems of production means that governments are likely to be less inefficient in producing research. This inefficiency exists even if the government knows the socially desirable level of research investment. Clearly, then, it would be inefficient to provide any private good through the public sector that could be efficiently produced in the private sector.

But in the case of public goods such as agricultural research, the preceding discussion shows that private markets are not likely to provide efficient resource allocation. Moreover, while there are various mechanisms that may provide an improvement over the *laissez faire* approach, each one involves its own inefficiencies. The choice among these alternatives, therefore, lies in assessing and judging which approach is most suited to a particular country's situation. Idealized tax or other pricing schemes for private provision of public goods may be politically infeasible and fraught with practical difficulties such as designing a different tax for each public good. The reliance on a patent or prize system presumes that the legal and political institutions will support an efficiently functioning capital market for the financing of private research, and that these institutions can successfully define and protect property rights that are associated with inventions. Under these imperfect but realistic conditions, even though the direct government support of agricultural research may be inefficient, it may not necessarily be any less efficient than the practical alternatives. In short, publicly funded agricultural research may well be justifiable as a feasible second-best alternative to patents, prizes, or tax and subsidy schemes.

4. Basic Research, Policy Research and Public Information

Traditionally, agricultural research was largely involved in applied work that led directly to genetic improvements in plants and animals that had commercial value, and to improvements in production practices associated with those plants and animals. With this kind of research there is a clear opportunity for the private sector to play a role, as is the case in the United States and other countries where intellectual property rights have been defined and protected.

However, there are also important areas of research and related information and policy analysis activities conducted by the agricultural research establishment that do not lead directly to products that have commercial value. These research activities produce information and knowledge products that are pure public goods, not club goods. The first case in point is basic scientific research. Although basic scientific research is the foundation upon which all applied discoveries and inventions are built, it is often difficult to associate any one invention with a specific basic research effort. Moreover, basic research is much more uncertain and speculative than applied research, and efforts are often much longer-term before progress is made or before advances lead to identifiable applications. An example is Watson and Crick's discovery of the structure of DNA in the 1950s. No one at that time could anticipate the contribution their discovery would make to the development of biotechnology 30 or 40 years later.

A second type of pure public good is the provision of economic data to support the efficient functioning of competitive markets. Economists know that relatively low-cost and complete information is essential to a well-functioning market system. Both the public good and economies of scale arguments of Schultz apply to the provision of economic information. Only large economic organizations are able to take advantage of economies of scale associated with the acquisition of information when large fixed costs are involved. With limited information for smaller economic organizations, markets may not allocate resources efficiently, and firms with better information are likely to be able to exert market power. A classic example is the information asymmetries between the large middleman who buys agricultural products from small farms in rural areas where market information is costly and difficult to acquire, and the resulting market power that the middleman exerts in this situation.

It is not easy to assess the value of publicly provided information in economic terms, but efforts have been made to do so in the United States (AAEA, 1996). A recent review of the U.S. Department of Agriculture's market information activities indicates that the $80 million annual expenditure on the provision of this information yields economic benefits to the U.S. economy at least one order of magnitude greater than the costs.

A third type of pure public good is policy research. Because markets do not function perfectly, the public demands that governments undertake economic policies, environmental policies, health policies, and so forth. But policies can be designed to achieve their objectives efficiently or inefficiently. Although this is not the exclusive domain of economists, a large share of policy research is done by economists, and the assessment of efficient policy design is the exclusive domain of economists. Also related to economics and other policy research is the science needed to support policy research. This includes a wide range of disciplines, including environmental sciences, health sciences, and nutrition and food technology.

As with basic research and the provision of economic information, it is not easy to identify or measure the benefits of policy research, and there have been virtually no attempts to make such measurements (Smith, 1996). Smith notes that most social science and related policy research produces information used by firms, households, and government, and this information is not related to commercial products. Another problem he notes is that, in contrast to research related to commercial products, and also in contrast with other forms of basic scientific research, it is more difficult to sort out successful social science research from the unsuccessful. An example is when an economist proposes a policy to address a market failure, such as an environmental problem. Suppose that after a policy is adopted by the government, it is learned that the policy is inappropriate for the problem it was supposed to address, and resulted in high regulatory costs without yielding commensurate environmental benefits. Should we then count these social costs against the research that led to that policy being proposed? And if so, how should we evaluate the expected benefits and costs of policy research, given the impossibility of predicting whether the research will be used to construct good or bad policies? Note that we could make a similar argument for any scientific research used to justify a government policy.

The Valuation Problem

In section 3.2 we discussed the free rider problem associated with public goods. Individuals do not have an incentive to reveal their true willingness to pay for public goods. In addition to this aspect of the public good problem, our discussion here of basic research, information, and policy research suggest some other aspects of the efficient provision of the these particular public goods.

First, the preceding discussion shows that there is a fundamental valuation problem associated with all types of research that produces knowledge or information that is a pure public good. When research results cannot be directly associated with a commercial product, the conventional methodology of estimating the shift in the supply curve caused by the research cannot be applied. To use the language of environmental economics, when research produces knowledge and information that are pure public goods, the fruits of research are *non-market goods*. Consequently, market prices for these goods do not exist, and we cannot determine the socially optimal amount that should be produced by using observable market prices.

Second, both basic research and policy-relevant research such as economics have the characteristic that advances in science come from the accumulation of knowledge associated with many research projects. Thus, it is difficult if not impossible to associate identifiable advances with one or a few individual projects. We know from cost-benefit analysis methodology that when a set of projects produce a benefit jointly, it is inappropriate to evaluate projects individually. The rate of return on any one individual project could well be negative, even though the rate of return on the set of projects could be large and positive. Consider, for example, the field of molecular biology and the associated inventions in biotechnology. Many of the basic scientific advances in molecular biology cannot be associated with a distinct commercial biotechnology product, even though none of the biotechnology products would be possible without a those basic scientific advances. Similar cases can be cited in economics and policy research. The large social benefits associated with the formation of the General Agreement on Tariffs and Trade, and the international movement towards free trade over the past 50 years, probably would not have occurred without the intellectual foundations provided by economic theory. Yet no one economist's work, and no single research advance, could be cited as the crucial discovery that led to this important development in public policy that has generated billions of dollars of benefits in the global economy.

5. Research in a Global Economy

Most discussions of the role of government in agricultural research and the provision of other public goods take place in the national context. But of course with the rapid globalization of agricultural technology and product markets, and with dramatic advances in information technology, the discussion of government's role in agricultural research needs to be put in an international context. Several aspects of the international dimension need to be considered.

A first relevant fact is that there are presently both public and private research being conducted on an international level. Agricultural inputs, including seeds and agri-chemicals, as well as mechanical implements, are produced and distributed by large multinational firms, and these firms conduct significant amounts of product-related research. In addition, basic and applied research are conducted by the international agricultural research centers that are members of the Consultative Group on International Agricultural Research. The publicly funded research within the national research systems is largely a public good and is disseminated widely throughout the world via conventional and electronic means. In the jargon of economists, the research benefits associated with national research programs "spill over" into other regions of the world. Thus, agricultural research has become an international public good, and this fact has important implications for the efficient provision of agricultural research. The efficient level of research, on a global scale, should equate the marginal willingness to pay summed across all individuals *in all countries* where the research may produce benefits. The discussion of appropriate policies for provision of agricultural research must therefore account for the international dimension.

The Uruguay Round Agreement on Trade-Related Intellectual Property Rights

To the extent that incentives for agricultural research can be created through the definition and protection of intellectual property rights through patents, the recently completed Uruguay Round agreement on Trade-Related Intellectual Property Rights is relevant. The agreement requires that 20-year patent protection be available for all inventions, whether of products or processes, in almost all fields of technology. Inventions may be excluded from patentability if their commercial exploitation is prohibited for reasons of public order or morality; otherwise, the permitted exclusions are for diagnostic, therapeutic and surgical methods, and for plants and (other than microorganisms) animals and essentially biological processes for the production of plants or animals (other than microbiological processes). Plant varieties, however, must be protectable either by patents or by a sui generis system (such as the breeder's rights provided in the conventions of UPOV - the International Union for the Protection of New Varieties of Plants). Detailed conditions exist for compulsory licensing or governmental use of patents without the authorization of the patent owner. Rights conferred in respect of patents for processes must extend to the products directly obtained by the process; under certain conditions alleged infringers may be ordered by a court to prove that they have not used the patented process.

Thus, the World Trade Organization allows for the patenting of microbiological processes, and specifically requires Member countries to provide for the protection of plant varieties through patents or other systems. Although patent protection under the agreement is for a period of 20 years after the patent application, less-developed countries are not required to observe these provisions until ten years after the creation of the WTO, that is, until the year 2005.

Assuming that the World Trade Organization is effective at achieving enforcement of the protection of intellectual property, the agreement raises several important issues related to government's role in agricultural research. The positive aspect of the agreement is that it creates a potentially much greater economic incentive for the development of agricultural technology in the private sector that will serve the needs not only of the more developed countries, but of all countries. To the extent that this private research effort displaces the need for national, publicly-funded research, it frees government resources for other uses.

However, this increase in private research incentive must be balanced against the monopoly power afforded by patents, as indicated in the discussion of section 3.3. This may be a particular concern at the international level for several reasons. The WTO agreement provides for 20 year patents, a length of time that may be longer than needed to provide sufficient incentives for a near-efficient level of private research investment. The substantial monopoly power afforded by lengthy patents has the potential to reduce the world-wide benefits of scientific discoveries. This monopoly power over technology also has implications for the distribution of research benefits. Most patents are likely to be held by individuals and corporations whose stock is help primarily by people in the richer countries of the world, so the monopoly rents from these inventions will flow to those countries. Moreover, the poorer countries that are at a competitive disadvantage because of various other factors, will be least able to afford to pay monopoly prices for new technology, and thus will be put at a further technological disadvantage relative to the richer countries.

The establishment of international intellectual property rights also may affect the way countries may use research and development as a tool of strategic trade policy. Many countries already have used government subsidies to research and development to become competitive in certain industries such as semiconductors and aircraft. Competitiveness in agriculture depends on the development of technologies that are suited to a country's resource endowment, location, and other factors. If countries acquire property rights to new food technologies, they may choose to restrict the availability of these technologies to other countries. This type of strategic behavior would result in higher world prices for agricultural commodities. Again, the restriction of food producing technology would impose the greatest costs on the poorest countries of the world.

Basic research, policy research, and information are pure public goods in the international domain as in the national domain, and thus are outside the scope of the World Trade Organization' intellectual property provisions. There is, therefore, a clear justification for the public provision of these components of agricultural research on the international level. However, it is important to note that there is an international dimension to the public good argument that goes beyond the national level. Suppose that a national government A decides to invest in basic research or policy research. Because this research produces knowledge that is a pure public good, it is readily disseminated world-wide. Consequently, other countries have an incentive to free-ride on the research supported by country A. The implication is that there is a role for international cooperation in the support of research if an efficient level of research investment is to be achieved at a global level. As yet, however, institutions do not exist to see that this sort of cooperation occurs.

6. Drawing the Line

Public institutions need to reassess where they draw the line between public and private research. Clearly, where research is closely related to the production of commercial products, when intellectual property rights can be defined and protected, and when other institutions such as capital markets function efficiently, the private sector can be relied upon to provide an efficient level of research investment. In many countries such as Brazil where there is a low level of private investment in agricultural research, the lack of an effective patent system is cited as a cause of private under investment. While this is true, it is equally important to note that a patent system without a well-functioning enforcement of property rights will not solve the problem. It is also important to recognize the limitations and inefficiencies of patent systems. Most importantly, a patent is a monopoly right to an invention. The social costs of these monopoly rights must be balanced against the incentives they provide for inventive activity. These same concerns apply to the intellectual property provisions of the Uruguay Round agreement.

The top priority for publicly funded research should be to provide knowledge and solve important problems that cannot be profitably supported by the private sector. Economists describe such research as a "public good." Basic research, such as the development of an understanding of molecular biology, is a public good because everyone in society can benefit from this knowledge. In contrast, private firms cannot benefit much from producing basic knowledge; therefore, they will under-invest in it from society's point of view. Generally, private sector firms cannot profitably invest in research that does not lead to a marketable product. But clearly, many aspects of science and technology—e.g., understanding the environmental consequences of human activity—are vital to human well-being even though they do not always lead to commercial products. These areas provide a clear justification for public support of research.

In addition, in the middle and high income countries the public's concerns about food quantity and availability are being replaced with concerns about food quality, environmental quality, and health. Research in the environmental and health sciences often is much closer to a "pure public good" than research on commercial crop or animal varieties, and clearly can be justified as part of the mission of publicly funded research.

These changes in priorities mean that the leaders of public agricultural research face new and increasingly complex challenges. In the United States, these challenges were codified in the 1990 farm legislation that defines economic, social, and environmental sustainability as a goal of U.S. farm policy. Other important challenges, such as food quality and safety, remain outside farm legislation. The principal regulatory authority for food safety resides with the Food and Drug Administration, not USDA. Rapidly evolving international agricultural markets and recent international trade agreements—the North American Free Trade Agreement and the Uruguay Round of the General Agreement on Tariffs and Trade—are also likely to change the economic opportunities for many U.S. producers, as well as food quality and safety issues for consumers. As a result, both the private and public sectors' research agendas will be modified.

The international agricultural research centers, and national research programs in other countries such as Brazil also face important new challenges in setting research priorities. While food availability remains a critical concern, especially where population growth rates are high, environmental degradation and its relation to the sustainability of food production is a major concern. The IARCs are under pressure by the international donor community to demonstrate the economic impacts of their research, as well as health and environmental impacts. Because most of the world's land with favorable climate and soils is already under cultivation, further production gains must come from intensifying production or cultivating marginal lands. However, emerging signs indicate that further research effort on intensive monoculture may not be able to sustain production growth sufficient to match the food demands of the growing world population. Cultivation of marginal lands raises other problems, including a limited potential for productivity improvement and increased environmental vulnerability (Food and Agriculture Organization, 1993).

The growing complexity of the task facing research institutions requires institutional priorities that are consistent with the public's needs and with the institution's personnel and resources. Research institutions face a classic economic investment problem: how to allocate resources — the research budget, facilities, and personnel — over time and across activities, to produce science and technology that meet the current and future objectives set by scientists, interest groups, legislators, and the general public? Solving this investment problem requires assessing the benefits and costs of both public and private research. However, there are important differences between investing in public sector research and conducting private research and development to produce a marketable product. First, as noted above, public sector research should produce the public knowledge that the private sector lacks incentive to produce. Second, because knowledge production is a creative but uncertain process, scientists need and expect substantial freedom to exercise their creativity and explore new concepts and ideas. Third, it is difficult to predict how research will contribute to the development of specific technologies or to public policy objectives. Fourth, policy objectives change over time, and are often vague and conflicting, while scientific advances come from years of sustained effort. The challenge facing public research institutions is to determine how they can rationally and systematically set priorities, taking into account these pressures and uncertainties.

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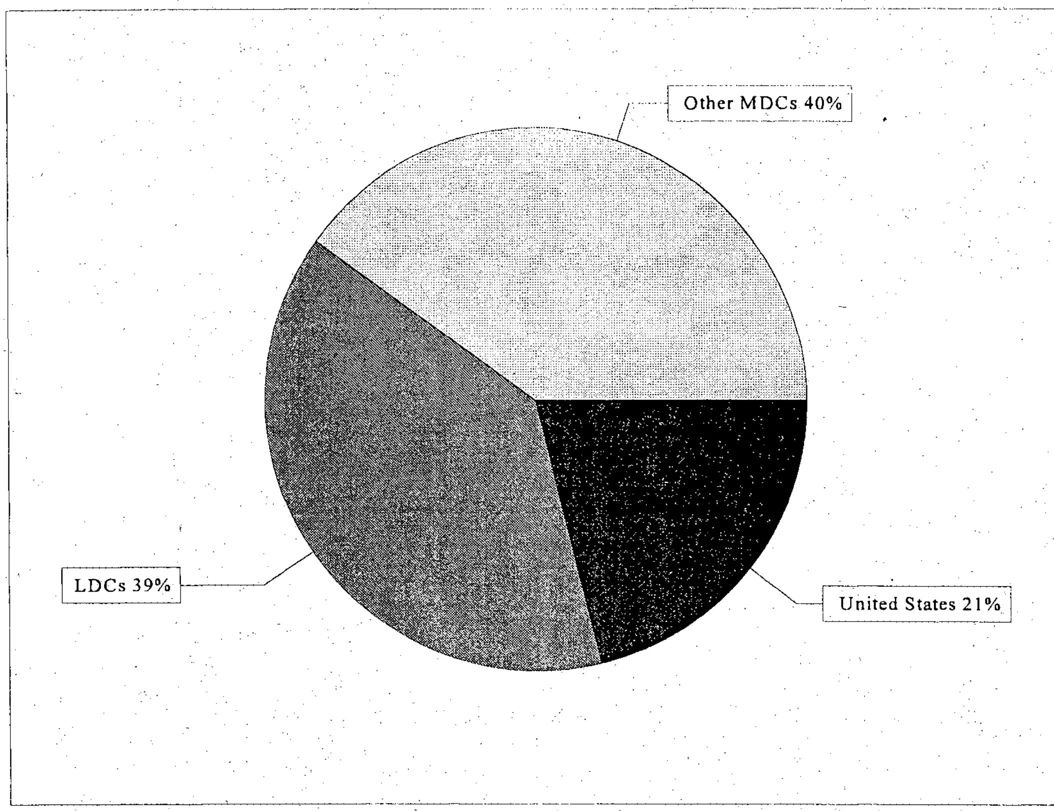
Figure 1: Global Investments in Agricultural Research and Development

Regional Shares, Annual Averages, 1961–95

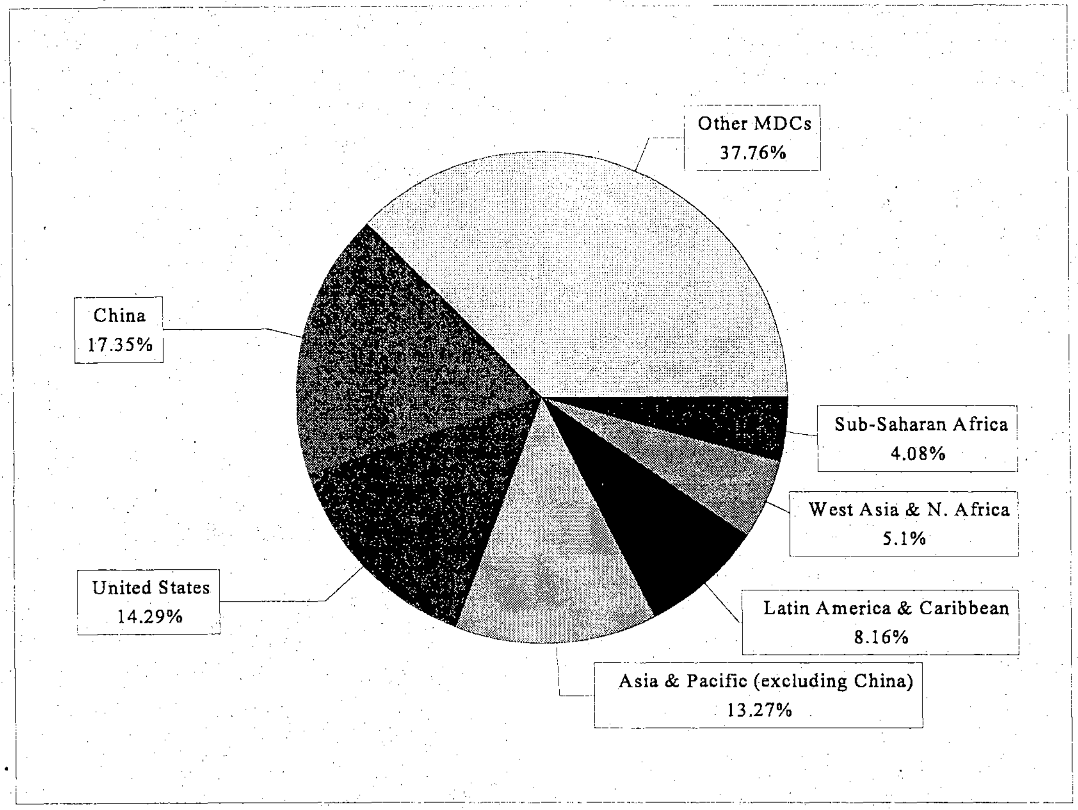


1961–65 Annual Average Shares (total, $3.36 billion 1980 PPP per year)

Source: Revised version of data reported in Anderson, Pardey, and Roseboom (1994).

Figure 2: Global Investments in Agricultural Research and Development

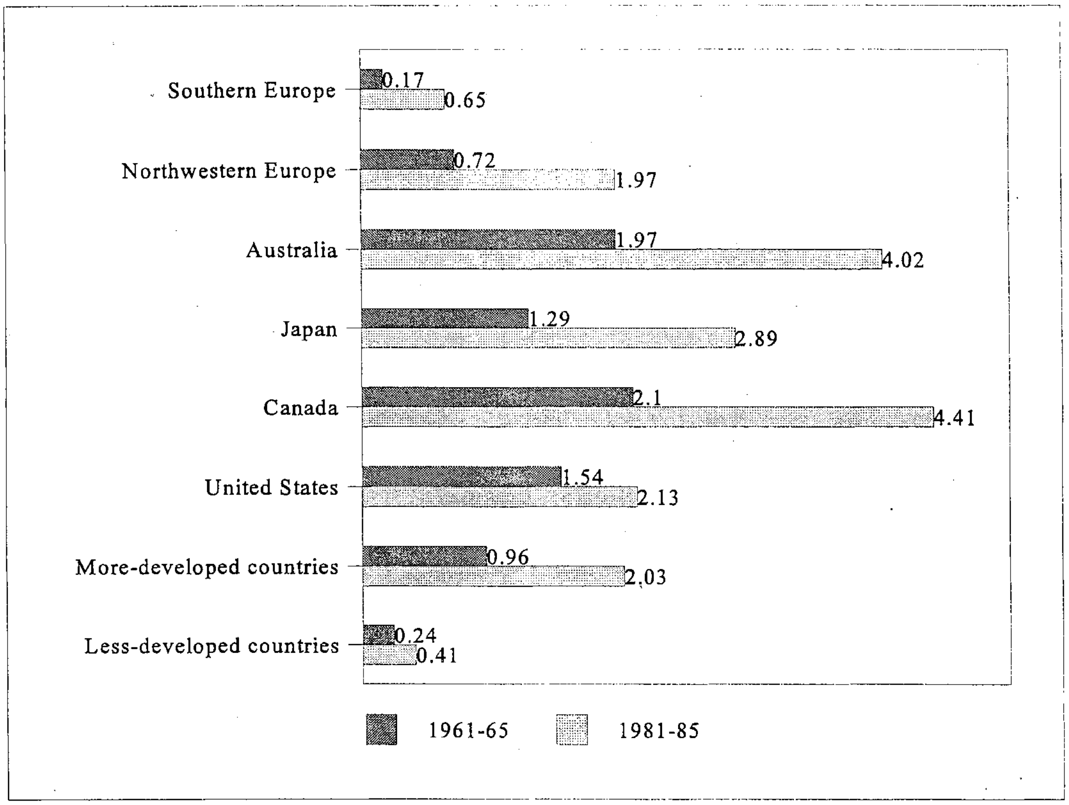
Regional Shares, Annual Averages, 1981–85



1981–85 Annual Average Shares (total, $9.09 billion 1980 PPP per year)

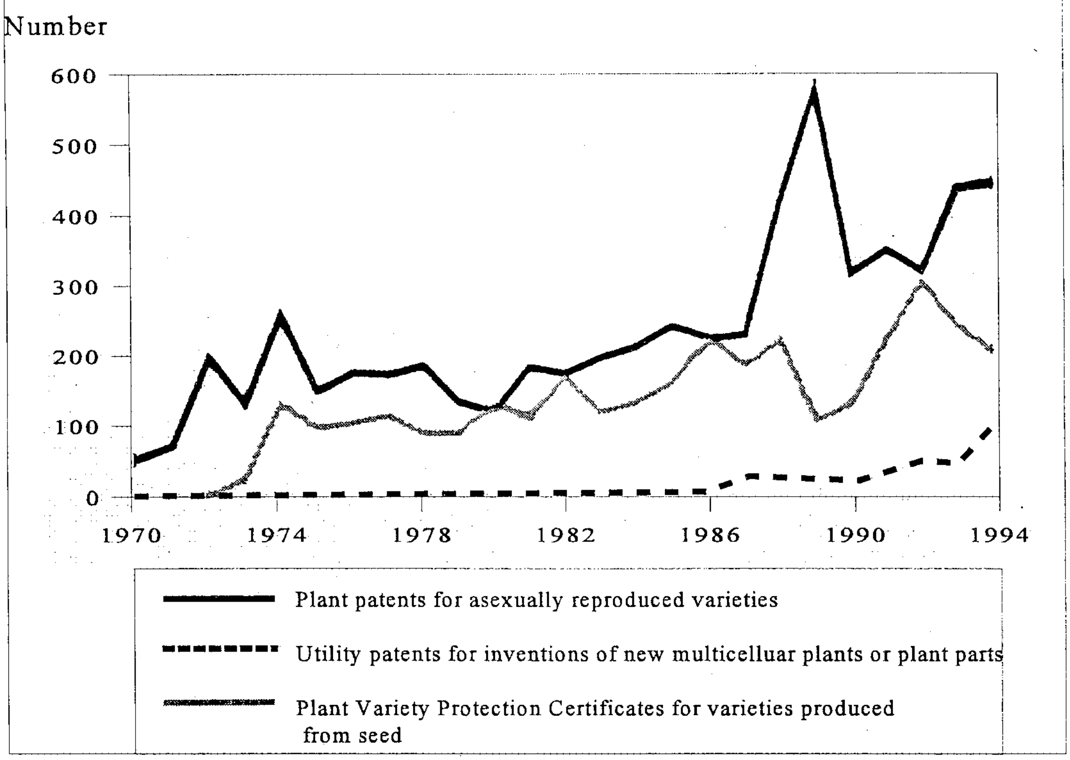
Source: Revised version of data reported in Anderson, Pardey, and Roseboom (1994).

Figure 3: World Agricultural Research Expenditures as percentages of Agricultural GDP, Annual Averages



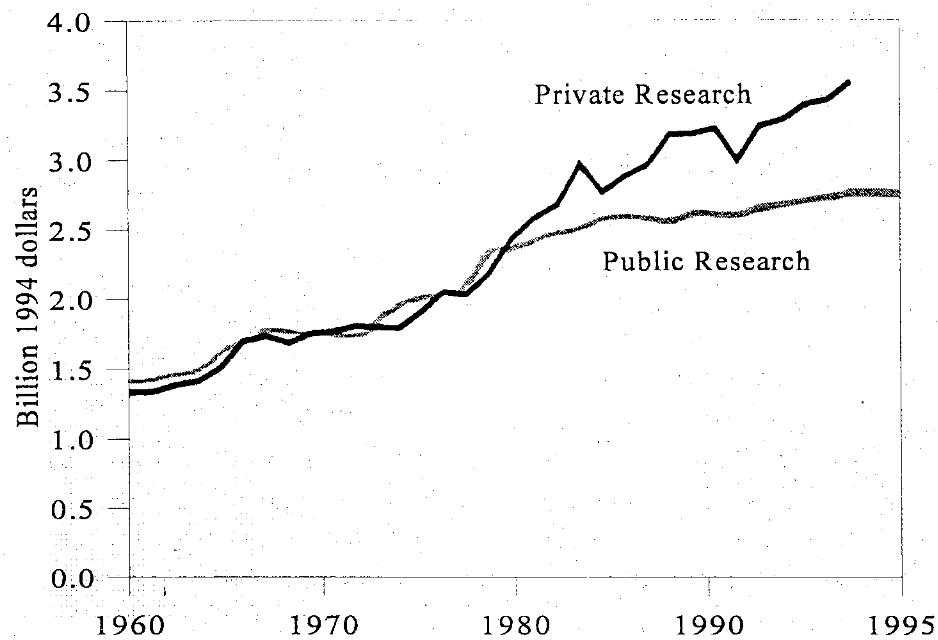
Source: Pardey (1991).

Figure 4: Annual Issues of Intellectual Property Rights for New Plants and Plant Varieties



Sources: Economic Research Service. Data derived from U.S. Department of Commerce, Patent and Trademark Office, CASSIS data base and USDA, *Plant Variety Protection Journals.*

Figure 5: Expenditures for Agricultural Research in the United States, 1960-94[1]



Annual expenditures adjusted for inflation by cost-of-research deflator.

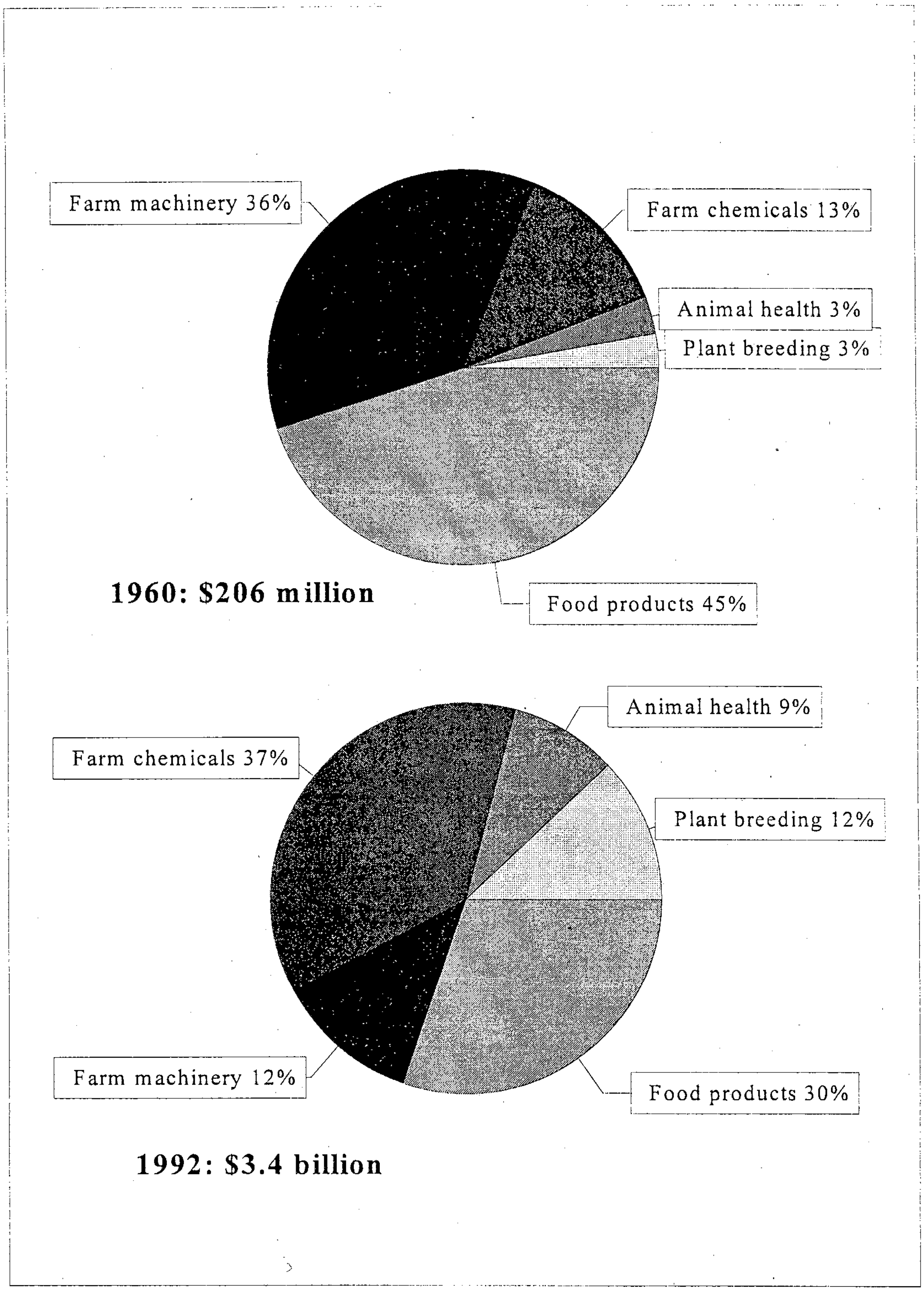
Sources: Economic Research Service. Private research data derived from Klotz, Fuglie, and Pray (1995); public research data derived from USDA, *Inventory of Agricultural Research.*

Figure 6: Shares of Agricultural Research Expenditures Devoted to Basic, Applied, and Developmental Research

	Type of Research		
Source	Basic	Applied	Developmental
Public	47.3	45.4	7.3
Private	15.0	43.5	41.5

Sources: Compiled by Economic Research Service. Public research data are for 1992 and from *Inventory of Agricultural Research*, USDA, 1993; private research data are for 1984 and from Crosby, Eddleman, Kalton, Ruttan, and Wilcke, 1985.

Figure 7: Private Agricultural Research by Industry



Source: Economic Research Service. Data derived from Klotz, Fuglie, and Pray (1995).

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