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AGRICULTURAL RESEARCH STRUCTURES IN A CHANGING WORLD

by

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Abstract

Society's demands on the agricultural research system are evolving from preoccupation with the yield and cost of individual products to concern with safety, quality and variety on the one hand, and environmental implications of production processes on the other. The system's response to the demands will be profoundly affected by the revolutions in biotechnology, ecology and legal protection of agricultural research property rights. The scope of the public role, as exemplified in land grant colleges, will be reduced in some areas, expanded in others. The incentives created by opportunities to market research products under patents protection posed managerial challenges within the university. The aim should be to use the market signals to help optimize research performance without compromising teaching, advising and other beneficial scholarly obligations with less direct financial rewards.

Agricultural Research Structures in a Changing World

Brian Wright and David Zilberman

Public and private sectors in the United States have been major partners in an multibillion dollar agricultural research, development and extension effort that has made possible the impressive rate of technical change seen in the sector over this century. Despite a widely-acclaimed record of high rates of return to public investment (Ruttan 1982), the public partners (USDA and state agricultural experiment stations) saw their share of research expenditures fall from 40 to 34 percent over the decade of the eighties (Huffman and Evenson 1993, Table 4.1), due to sporadic cuts in public support levels that are mainly traceable to exogenous budgetary pressures. Over the same period total expenditures increased, however, from 3.9 to 4.8 billion dollars (at 1984 value) due to a rise in private expenditures.

The budget cuts are the most obvious but not necessarily the most important forces for change. Currently pressure for more fundamental changes in the nature of this collaboration is being engendered by qualitative changes in the social demands made on the agricultural research and extension system, in the scope and nature of scientific opportunities for discoveries, and in the potential rewards for researchers.

In this paper we consider the implications of these changes for the nature of public and private agricultural research. We focus on land grant institutions like U.C. Berkeley and their relations with the private sector in pursuing research and development.

First we consider the nature of the changes in demands on the agricultural research system. Then we review the reasons why both the public sector has a valid economic role in the research and extension system. In section 3 we consider public and private sector responses to the new research demands and opportunities. Then follow a discussion of the implications for the land grant university, first with respect to institutional structure, in Section 4, and then in Section 5 for performance of the university's roles of teaching as well as research and extension. Conclusions follow.

1. The Evolution of Research Demands

Historically the social demands on the system have focused on a cheaper and more stable supply of familiar foods and fibers, accompanied by some ill-defined concern to maintain "family farms" as economically viable units in a modern society. The cost-decreasing, yield-increasing innovations the system produced for farmers satisfied these social demands successfully, even if the economic pressure on farmers associated with the production cost reductions, competition, and inelastic demand induced effective political pressure for compensation from the public budget.

Now, however, society's demands of the farm sector have become much more complex. Consumers are concerned with the health risks of chemical residues in foods . Other topics attracting increasing interest include the herbicides and pesticides released into the environment by farmers, the effects of erosion on land and water quality, and the problem of animal wastes and most recently of methane emitted by belching ruminants. Standards for animal rights are being advocated for veal calves and poultry. Clearly the farming process itself is increasingly being subjected to direct social constraints, rather than being viewed as only indirectly socially relevant as the means to achieving a prosperous farm sector and a cheap and secure food supply.

At the same time consumers with increasing incomes and no intention of eating or drinking more are looking for higher quality, novelty, variety and constant availability in their foods. These objectives are not obviously mutually consistent, especially if the research approaches that produced high yield and low costs are adhered to.

Scientists and innovators are being asked to furnish production processes, and new products, that respond to these multiple social concerns, and there will be an increasing demand for products and services that can help management in this complex and dynamic environment. Indeed the multifaceted interactions that constitute an agricultural system will increasingly be the subject of analytical attention. Beyond biotechnology lies the challenge of ecological agriculture. This is far more demanding than the more narrow, often organism specific, focus seen in much of modern medicine, for example, as well as in that part of agriculture that has achieved the greatest yield increase, the cultivation of an individual crop via the exclusion of competitive species by some artificial means. Fortunately the challenge comes at a time when the scientific capacity is being transformed by the revolutions in biotechnology, information processing and ecology.

Besides improving the prospects for pursuit of the traditional productivity objectives, the new biological techniques make possible previously unimagined qualitative transformations of plants and animals. They seem to expand greatly the potential for satisfying the new demands for benign production processes, on the one hand, and an array of improved consumption characteristics on the other.

Already scientists have been able, for example, to transfer the pesticidal qualities of Bt into agricultural plants, which might help reduce chemical pesticide use. On the other hand genetic manipulation has also made possible delivery of better-ripened fruit, such as the Calgene tomato with less damage and wastage. No doubt a slew of more impressive breakthroughs can be anticipated in the years ahead.

The advent of the new biotechnological innovations has been fostered by new legal protections in the form of the Plant Variety Protection Certificate (PVPC), established in 1970 and extended in 1980, and then the expansion of patent protection to life forms. Similarly the market for software and databases has been sufficiently (if not optimally) developed under the evolving law regarding copyright protection that it has made the personal computer a productive and popular management tool for farmers and farm advisers.

In the new environment, what changes should we want, and what changes can we expect, in the public and private roles in agricultural research? What is the appropriate structure of public-private collaboration in agricultural research and extension? How should resources be allocated to research areas and projects? And how should public (and private) researchers be rewarded? These are the questions addressed in this paper.

2. Why Public Research and Extension?

As a preliminary, it is helpful to keep in mind the reasons why we have a public research system in the first place. After all, we rely on the private sector to produce other products, including food, with profits from private sales as the incentive. Public provision of research and extension has been justified by the argument that the private incentives fall short of the public gains at the margin. Important "externalities", benefits (or costs) not captured in private profits, are associated with public research inputs, outputs, or the process itself. This argument has much greater force for some areas of effort than others.

It is widely accepted that pure knowledge, not embodied in any product, is an eternality, a "public good", the benefits of which are properly made available free of charge because they are "non-rival"; use by one does not reduce the supply available to others. The product of successful basic research is of this type. This desirability of free provision is fortunate, for it is very difficult to exclude non-purchasers from acquiring such "disembodied" information, and since the information is often of quite general use the number of potential "free riders" is often very large. It follows that basic research is mostly produced in, or at least supported by, the public or non-profit sectors.

Basic research findings feed into the applied research areas, which tend to be more industry-specific. In many areas the fruits of applied research are at least partially capturable by its producer, for two quite different reasons. The paying user of disembodied applied process discoveries reaps the benefits to the extent that the user dominates the industry. For example, an advance in irrigation-equipment manufacturing techniques would be likely to benefit major manufacturers. Furthermore, much applied research and development produces innovations that are embodied in products, such as a machine or a drug, that can be sold for profit in private markets, and protected from copying by patents or secrecy. In these cases the derived private demand for applied research may well be adequate, if not optimal.

In agriculture, the producers of applied research have historically had little scope for capturing sufficient compensation from the market to justify their efforts. Most advances have been either yield-increasing or cost-reducing. Some of these advances are embodied in plants or animals that can reproduce, passing on the advances to later users, and spoiling the innovator's prospects for lucrative sales in the absence of effective legal protection. Others are process advances such as new techniques of crop cultivation that can be easily copied by diligent observers. Given the extremely competitive nature of agricultural production, the rewards accruing from use within the innovator's own farming operation are typically a tiny fraction of the full social value.

There are of course prominent exceptions to these generalizations. Private hybrid corn innovators have prospered because their product cannot be successfully reproduced by their customers. Hybrid chickens are also produced privately. Mechanical and especially chemical farm inputs, originating in other sectors, have historically had patent protection. This has not always been very effective. Eli Whitney's cotton gin, to take a famous example, was so widely copied, despite patent protection, that it was necessary to award him a prize to provide him, ex post, a significant return for his innovation.

Given the anticipated opportunities for innovation, on the one hand, and the lack of privately appropriable returns from many types of applied innovations on the other, the public sector role in supporting agricultural research has been unusually large, and has included the applied development and dissemination of techniques and products that in other sectors is left in the hands of the private sector. Thus the historical role of the public agricultural research complex covers the whole range from basic scientific investigation to the farmer's field. In the United States the land grant universities such as the University of California at Berkeley cover this span, in large part integrated within a college of agriculture and/or natural resources.

Three aspects of the structure of the land grant agricultural research system suggest the types of externalities important to their mission. The first is that it is a decentralised system of vertically integrated individual institutions, dispersed across the states with substantial funding from state as well as federal sources. Second, its basic structure is program-oriented rather than project-oriented, in that its staffing is predominantly on a permanent basis. Third, the research mission is pursued in concert with an educational mission; researchers are also university teachers and students and others involved in public education.

The decentralisation reflects the fact that many applied research problems are locally specific. Pests, diseases, plant varieties and cultivation practices differ across states and even counties. An institution that is close to the problem is more likely to respond effectively. Thus dispersion of the applied research function makes sense. The dispersion of the basic researchers along with their applied colleagues, as in the land grant universities, allows both types to take advantage of the knowledge externalities available due to close informal contact. The experience of institutions set up with a more exclusively applied focus, such as the International Rice Research Institute, apparently has led them to an increasing appreciation of a permanent, in-house, more basic research capacity.

Concentration on local problems also reflects the fact that their solution receives the greatest political support from the agricultural sector. Yield increases and cost reductions supplied gratis to all producers tend to reduce output prices rather than increase profits. But to the extent that the effect is only local, the price reduction response is muted, and the local benefits to the sector are more likely to be positive. Given productivity increases offer greater benefits if they occur on a national or international scale, but the benefits would tend to go to consumers, who have little influence on the system. Local problems get the most attention, and the spatially decentralized research system is well suited to addressing them.

The permanence of the research and extension staffing means that there is an accumulation of institutional capacity in the form of knowledge and expertise to respond quickly and effectively to emergency problems, such as the poinsettia whitefly or the suddenly-apparent selenium toxicity to waterfowl at Kesterson reservoir in California, as they arise. This "option value" could be important to the extent that the same response cannot be had as efficiently from the private sector in the form of temporary consultants or contractors. When the whitefly struck California, would it have been better for each affected farmer or even the state government, to have sent out for bids from private fly-problem-solvers? The argument for public provision of quick access to a standing capacity for flexible emergency response seems similar to the argument for a publicly supported standing army or fire brigade (granted some would argue against the latter). The argument has force if in-house performance incentives are more appropriate, if the externalities from easy contact with and access to basic researchers are important, and/or if it would be difficult to know what contractor to choose if the expertise were not already present in the public sector.

The association of research with teaching is a practice that is widespread across the academic spectrum. The interplay between functions is difficult to analyse and not well understood. Obviously class time competes with research time, for faculty and students. On the other hand the functions are complementary; in a sense each offers positive externalities to the other. Students who learn how to apply their classroom learning by participating in real research in a critical environment under the supervision of their professors can reap educational and motivational rewards. Furthermore their work has an actual social contribution, in contrast to fictional educational exercises. Their experience might also help students make better and earlier choices about the direction of their careers. Such benefits would normally become more available as the student advances in his or her academic career.

For professors and other teachers, involvement with institutional research helps keep their teaching relevant to current problems. This is likely to be more important for advanced undergraduate and graduate classes where there is usually more discretion about choice of subject matter and teaching tends to be more focused on research challenges. As researchers, their involvement in teaching, especially in advanced courses, helps broaden their perspective beyond their currently pressing research challenges to comprehend current work in other corners of their academic field, and in related specializations. Since scientific progress often results from drawing links between lines of investigation, involvement in teaching can encourage faster progress in research.

The above discussion has focused on some rationales for the current structure of agricultural research, as seen in the land grant system in particular. The features noted have their drawbacks, of course. Decentralization means inevitable duplication of some research and of teaching functions. Permanent employment on a program basis makes it possible for deadwood to accrue and for the institutional culture to tolerate sloth and lack of responsiveness to social demands in both education and research. Teaching demands can divert bright minds from vital research tasks, and, on the other hand, research demands are currently being blamed for neglect of undergraduate teaching in the universities and colleges in general.

The social optimality of the land grant approach to agricultural research in trading off the advantages and disadvantages of its institutional design has not been scientifically established, of course. A more modest claim that it has served society quite well over the years would, we believe, seem reasonable to many informed observers. Whether or not that claim is true, the relevant question now is how the existing structure of public and private collaborative research will respond to changes in the social, institutional and scientific environment .

3. Private and Public Sector Responses to the New Environment

We have some evidence already about the private sector response to the new opportunities. There has been an explosion in the private creation of new varieties after they were covered by the PVPA, and this occurred with conventional technology; it was not caused by the new possibilities associated with genetic engineering. One might have anticipated this private sector response from the history of successful private production and marketing of hybrid corn varieties, which had some natural protection from unauthorized duplication by customers. Now advances in biotechnology have opened up a whole new technological frontier, and patented life forms and other genetic engineering products are already being marketed to agricultural producers as well as to other industries including prominently those in the health sector. Furthermore there is a complementarity between the institutional and technological advances. Modern analysis of DNA is likely to make policing of life form patents more effective.

The ability to patent and copyright has also changed the marketing possibilities for public and non-profit research institutions and the researchers who are employed in them. Whereas previously they had few opportunities to sell their output (as distinct from their services as research inputs) the institutions, and their employees, now face very significant rewards for success in meeting market needs, the diversity of which is reflected that two of the most successful to date are the Cohen-Boyer gene-splicing patent and Gatorade. An agricultural example is that the domination of the market for strawberry varieties by the University of California, Davis.

4. Implications for Institutional Structure

(1). Vertical Integration of Public Agricultural Research

The new opportunities to sell the property rights to embodied research outputs will affect the public and private research structures in many dimensions. Perhaps the most obvious is that private for-profit applied research is feasible for these new innovations, so that the public role need not be vertically integrated right down to the farm gate, as it has been for other agricultural innovations without capturable property rights. Somewhere between basic research and extension, an interface can develop between the public and private innovation institutions. The transfers will tend to be vertical, with the private party downstream (on the applied side). If the transfer happens at the pretechnology stage, before the knowledge is embodied in a marketable product, it is similar to the public provision of technology to farmers, in that the private party acquires a free good. In this case though, it is an input to further (private) research and development, rather than directly to the production process itself. This distinction can be crucial.

If a potential purchasing firm is unprotected by pre-existing market power, it might well be reluctant to invest in the development of the technology to the marketing stage, for fear that others equally free to acquire the public technology gratis might beat it to the punch, or even copy the technology developed for its product, which might well be too applied to the novelty and non-obviousness tests required for patenting.

This might explain why the Commonwealth Scientific and Industrial Research Organisation in Australia found that they literally *could not give their technology away*. A policy of exclusive licensing was adopted to elicit greater interest in adoption of its discoveries by the private sector. Where this consideration is important, the public/private interface will tend to lie beyond the stage at which the first property right is acquired. Significant patenting will occur in the public part of the research sector. Private participation will replace some public efforts at the applied end of the research spectrum. This is already happening in other technological areas such as irrigation, where the dealers are the final agents of information transfer to farmers; a major part of extension ends at the dealer's yard. But substitution of private for public research will remain concentrated in the development stage, where further patenting will, of course, occur.

Another obstacle to direct technology transfer, found by Postlewait, Parker, and Zilberman in a survey, is the reluctance of in-house research departments to encourage the purchase of technologies that were not developed in the company itself. As a result , licenses to some of the most advanced technology developed in the U.S. have not been purchased by local companies. For example, a Stanford researcher invented an music chip for electronic keyboards. Despite the technology's obvious potential to revolutionize the industry, no American company wanted to license the chip, and eventually Yamaha licensed the technology and wiped out the competition.

Where the private innovator has market power, its research may, as mentioned above, extend up towards basic research, even without the legal protection of property rights. In this case the innovator tends to be a large firm with a structure of bureaucracy possibly similar to that of a public institution.

Some other large firms take the opposite tack, acquiring technology by purchasing small companies that were developed around a certain innovation. Some large chemical companies lurk around trying to absorb promising innovative companies. In turn, these young companies need the marketing capacity of the big companies and they may seek an adopting parent. (That is one reason we expect purchasers of university licenses to be larger companies.) In effect some of the big companies are *marketing* organizations that rely on small R&D companies to develop a diversified product mix. They may also be potential customers for university research rights.

Increasingly, extension personnel are becoming more involved in giving policy advice to government and to public agencies, and in the facilitation of environmental management and controls. In these roles they extend knowledge produced by university research. As the downstream reach of extension is rolled back in some areas of technology, it is expanded in other areas to meet changing needs.

(2) University Marketing Arrangements

The possibility of patenting research findings in a public institution such as a land grant university raises many issues, among which are:

How will the rights be marketed?

Who shares in the revenue?

Should the university participate in development investment?

Answers to some of these questions already exist (at least provisionally) in the structure of the "Office of Technology Transfer" (OTT) or of the "Office of Technology Licensing" (OTL), itself an institutional innovation seen in several universities.

The leader is Stanford, whose OTL is available for patenting and licensing the research of any faculty who wish to use it. The proceeds are divided as follows: After 15 percent is taken off the top to finance the OTL, net royalties are split into one-third shares for the inventor, one third for the inventor's department, and one-third for the university.

The University of California has a similar systemwide office that awards university employees on a sliding scale, with 50 percent of the first $100,000 of net royalties, 35 percent of the next $400,000 and 20 percent of any higher amounts going to the inventor. In contrast to Stanford, faculty at the University of California must use university services to patent university research. Some campuses, including Berkeley, are now developing their own decentralized offices to offer better service to their faculty.

Thus researchers at both public and private universities can stand to gain a substantial share, of the realised value of their discoveries , and their departments and the whole institution also stand to gain. Paradoxically, *the explicit incentive appears greater in these institutions than in the typical large private firm*, where the patents of employees are routinely assigned to the firm via prior contractual commitments and there is usually no significant explicit reward to the patent recipient.

What has been created is a monetary market for innovation output within the context of the hierarchical bureaucratic structure of the university. Given the current popularity of markets as allocators of resources, the merits of this institutional innovation, for the university as well as for the researcher, should need little elaboration.

Some universities are now moving downstream again beyond patenting to financial participation in development of their patented technology, either directly or through a related institution to avoid legal problems of product liability. It is time to question whether the university is an appropriate institution to handle the challenges and risks of participation in venture capital investment. Private inventors are notorious for having exaggerated views of the financial prospects of their brainchildren. In at least one case investment in venture capital has reportedly placed the financial health of a major private university in jeopardy.

5. Implications for University Performance

(1) Research Efficiency

As noted, the frontier technologies we have been discussing happen to offer unusual opportunities for market returns due to patent and copyright protection. Patents and copyrights are very effective at using the researcher's own information, informed by market pressures, to choose between research topics according to his or her capabilities, research costs, the probability of success, and the value if successful. Since research resource management is characterized by uncertainties and informational shortages, this utilization of the researcher's information and his or her market expectations is extremely important. The disclosure mandated under patent law also makes the information discovered more accessible for other members of society who can use it in further innovation efforts.

If instead a prize (money or promotion) is awarded for achieving a pre-specified goal, the researcher's information about the market value of success is unused unless an effective means of gathering it is found by the prize-setter. This does not matter if the latter has accurately identified an appropriate social goal. Some of the most important technical advances have occurred in response to prize incentives, including the technique of food preservation by canning, and the navigational chronometer. But in research an important part of the individual's skill is often the ability to know what questions to ask, what goals to set, given the economic environment and the technical possibilities, as set out in the (as yet incomplete) theory of induced innovation. (see for example Binswanger and Ruttan, 1978). Prizes for achievements defined ex ante do not reward such skills. If we assume the prize setter has similar skill and the latitude to use it , there may be no problem, but this is a big assumption.

Likewise, if research proposals are chosen by competitive bids (an increasingly popular trend), private information about capabilities and success prospects is also lost to management.. When the research process is managed by central direction of research inputs including personnel, all of the private information about capabilities costs, probabilities, and market returns may be neglected. (For more on this see Wright 1983, 1985.)

But patents, copyrights and similar awards have their problems as research motivators. The race to be first to patent may involve wasteful duplication of effort on similar projects by personnel within or between institutions, especially if the line of research is very responsive to economic incentives (Barzel, 1968, Wright 1985). This is made more likely by the need for secrecy about research strategies in preserving a competitive advantage. Collaboration with complementary research colleagues may be discouraged for the same reason, or because of envy or spite or due to problems deciding and committing to shares of credit. This problem will be particularly severe in large teams such as a research laboratory where individual contributions are difficult to verify.

In addition the patent incentive might be too powerful in the sense that it distracts attention from other important tasks with less direct motivations. For university personnel, these could include teaching, advising and other institutional services, on the one hand, and research (such as more basic investigations) which yields non-patentable knowledge.

Similar kinds of objections to providing value-based rewards for innovation are increasingly expressed in the business management literature, largely influenced by recent Japanese thinking associated with the "Kaizen" (gradual improvement) system. They may also explain the observation that similarly large private firms in the United States generally choose less high-powered, more implicit, rewards for their employees than the arrangements now becoming popular in research universities.

In the case of universities, it should be borne in mind that many of the problems with the new incentives, including duplication, envy, and misdirection of effort already exist in the system of rewards based on implicit criteria imposed ex post by deans and/or academic peers, from tenure and merit increases to general prizes such as the Nobel Prize, reflected in the prescription "Publish or Perish." The advent of a parallel system of market-determined rewards might to some extent offset the distortions of the traditional implicit incentive structure. In principal, this issue should be amenable to empirical resolution for specific cases.

(2) Social Externalities

The market transfer of knowledge has been emphasized above. Two points are worth bearing in mind about the associated social contribution. First, even when an innovation is patented, it usually transfers benefits greater than its market price to consumers. It will often reduce, directly or indirectly, the price of some consumer good, generating consumer surplus. Furthermore, the disclosure inherent in the patent process will furnish a knowledge externality, as mentioned above. In short, monetary returns do not necessary furnish adequate rewards for invention, even in some cases where a strong patent is obtained. In these cases, public employment of researchers, and/or other incentives such as prestige might be beneficial.

Second, it would be a grave mistake to conclude that prior to the recent innovation in biological research property rights the university research contribution to private research activity would be negligible. As Nelson (1986) concluded from a 1984 survey of research managers by Levin et al. in 1984, the role of university research was especially important in biologically-based industries (p. 187). More generally, "university research rarely in itself generates new technology; rather it enhances technological opportunities and the productivity of private research and development, in a way that induces firms to spend more both in the industry in question and upstream" (p.188). This stimulation is at least partially local. As Jaffee (1989) and Acs et al. 1992 show, states with high university research expenditures also have more industry research expenditures, more patents, and more reported innovations. The locations of Silicon Valley, the Route 128 area near Boston, and the emerging biotechnology industries near Berkeley and Davis support this view. As argued above, the spread of university patenting of life forms should expand this complementarity, especially in biological applications including agriculture. This predominantly complementary rather than competitive role of patenting by different types of institutions was found by Evenson and Dolalikar for India; bestowal of patenting rights on multinationals induced increased local patenting.

(3.) Cash Cows?

As we have seen, the sale of research products can be a multimillion dollar enterprise for universities. The funds can help retain productive researchers who might otherwise go to industry, and can also augment the university' resources. But one should keep a realistic view of the possibilities here. Stanford is singularly successful in this research marketing area. Yet Stanford gets only about 11 percent of its budget from industry (Postlewait, Parker and Zilberman). Its highly successful OTL brings in about $25 million per year.

6. <u>Conclusions</u>

The agricultural research system is facing fundamental changes in the nature and complexity of its challenges and its opportunities. We can expect that this will result in less vertical integration in several areas including production of new plant varieties, leaving a greater role for the private sector in applied research.

In other areas, the role of university research and extension may well expand. Many of the coming social demands can only be met if complex innovations are achieved in institutions and policies. The research role of the university, in addition to furnishing new technologies must be to facilitate the debate on options and help shape the necessary institutional adaptations.

In informing people about alternative risky choices, for example pesticide versus irradiation to preserve foods, the university should exploit its educational role in teaching and extension, as well as its research capabilities.

The new opportunities and challenges bring with them new management challenges. The potential for private gains from research property rights must be handled carefully. Its introduction of market signals for researchers will be a very positive development if it is not allowed to distract excessively from teaching, advising and collaborative research activities with a less direct financial reward. To ensure that the latter does not happen, careful research is warranted regarding the structure of license-sharing arrangements and the determination of relative research contributions from collaborative projects.

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