ECONOMIC ANALYSIS OF BIOTECHNOLOGY RESEARCH

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The potential role for economics in biotechnology research does not differ from the role of economics in examining research in general. There is a substantial literature on that topic. Hans Binswanger has posed four questions that an economic analysis of technical change should address. These questions provide a useful roadmap for thinking about the role of economics in biotechnology research. The questions are: (1) What quantity of resources should be allocated to research, and how should it be allocated? (2) What policies provide the incentives necessary to bring about this optimal allocation? (3) How do economic variables affect the nature of technical change? (4) How do policies unrelated to technical change affect the rate and direction of such change?

To Binswanger's questions, I would add another: What are the economic consequences of a particular biotechnology innovation? By economic consequences I mean welfare effects —changes in consumer and producer surplus, yes, but including distributional impacts and nonmarket effects. When posed prior to the initiation of research ("preresearch" hereafter), this question is implicit in Binswanger's first, for we must surely have a clear idea of economic consequences if we are to discriminate among research directions. When posed after the innovation is developed but before it is adopted ("preadoption" hereafter), this question is relevant to potential adopters, to policy makers, and to others who may be affected by any structural consequences. When posed after adoption ("postadoption" hereafter), the answers to the question provide empirical results to guide preresearch and preadoption analysis of other technologies.

A typology of economic studies that emerges from these questions is as follows:

I. What are the economic consequences of a particular technology?
   a. Market effects
      1. Short-run—Measurement of immediate incentives for producers to adopt, given current prices and resource allocation.
      2. Long-run—Measurement of changes in producer and consumer surplus from the innovation once prices and resource allocation have adjusted, including distributive effects by income level, resource ownership, etc.
   b. Nonmarket effects
      1. Externalities—Measurement of costs or benefits that are not reflected in changed market prices, such as air or water degradation or improvement.
      2. Undetected effects—Assessment and evaluation of the risk of unforseen effects of the technology.

II. What quantity of resources should be allocated to research, and how should it be allocated among projects, between basic and applied research, and between development and diffusion?

III. What policies related to research and adoption will maximize welfare?
   a. Price policies—What effect do they have on incentives for research and adoption of various kinds of technology?
   b. Intellectual property rights—How do they affect incentives for research on various kinds of technology?
   c. What are the costs and benefits of regulations affecting testing and use of innovations?

IV. How do economic variables affect the nature of biotechnology change (will differing land/labor endowments across regions induce differing paths of change?)

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V. How do policies unrelated to biotechnology, such as price supports, taxes, or minimum wages, affect the rate and direction of such change?

The agricultural economics literature includes examples of both *ex ante* and *ex post* analyses of most of the above issues. The *postadoption studies* of course had no effect on the research and adoption patterns of the technologies studied, but they did demonstrate high rates of return to investments in early biotechnology research (Arndt and Ruttan), and they offered some insights into the factors important in fostering development and adoption (Griliches, 1957). An example of a *predevelopment study* is the one in which Davis, Oram, and Ryan rank the value of incremental research in rice, potatoes, wheat, and a number of other crops, and estimate the distribution of benefits between producers and consumers and between developed and developing countries. Other predevelopment studies are reviewed in the Arndt, Dalrymple, and Ruttan book. Recent *preadoption studies* in the area of biotechnology are the growth hormone studies by Lemieux and Wohlgenant, and by Kalter *et al.*

Rather than to undertake a review of past economic studies of research, these comments now turn to some particular shortcomings of economic research to date as it relates to the biotechnology area.

METHODS FOR TRANSLATING EXPERIMENTAL RESULTS TO MARKET EFFECTS

Zvi Griliches (1958) estimated that the discovery and adoption of hybrid corn led to a 15 percent shift in the supply function, and he examined with some care the time path of economic consequences. His work spawned a generation of similar studies of other innovations (see Norton and Davis for a review). One component of the study that was never challenged was the procedure by which the 15 percent shift was estimated. In describing this procedure, Griliches states "... for my purpose, I assume that the superiority of hybrid over open-pollinated varieties is 15 percent, the lower figure in most estimated ranges [for example 'Plant breeders conservatively estimate increase in yields of 15 to 20 percent from using hybrid seed under field conditions. They expect about the same relative increases in both low- and high-yielding areas' (USDA, Technology on the Farm, p. 7)]."

To assert that this is a rather casual approach to estimating the fundamental supply shift is no reflection on the usefulness of Griliches' seminal work. However, it is a reflection on those of us to follow that we have made so little advance in thought about how to do this. Peterson's study of poultry research made some advance by acknowledging that the reduction of input-output ratio for *one* input (pounds of feed per pound of gain, output per unit of land) does not imply an equivalent percentage reduction in cost, nor an equivalent shift in the supply curve. The Kalter *et al.* and Lemieux-Wohlgenant studies have expanded the dimensions of the problem to recognize that technological change can selectively affect the productivity of different inputs (as in output per animal versus output per unit of feed) and different components of output as well (protein versus fat, for example). This directs our attention to the issue of how to measure shifts in the micro production function from experimental or other data at hand, including input and output biases in the shift, and then to the issue of how these shifts are translated into market supply shifts for outputs and market demand shifts for inputs. The Lemieux-Wohlgenant study is the most explicit in addressing the problem with firm-level data and a firm-level cost function, yet it lacks a clear, repeatable method of utilizing experimental information. While it is true, as Davidson and Martin observed many years ago, that experimental yields exceed commercial yields, we do not at present have a consistent conceptual apparatus for making use of the data (Bernhart and Perrin).

THE EFFECT OF PROPERTY RIGHTS ON PRIVATE RESEARCH

Research produces knowledge, and knowledge is a classic public good. It is nonrival in use, and there are spillover effects in its production (the production of a bit of knowledge by one person usually changes the costs or returns for producing other bits of knowledge). Without intellectual property rights, private incentives to produce knowledge are tiny compared with potential social benefits. This was substantially the case for biological technology prior to 1970, because knowledge embodied in biological life forms could not be patented, although processes and products from these life forms could.

This situation has changed dramatically, first due to the Plant Variety Protection Act of 1970 (PVPA) and second due to the Chakrabarty decision of 1980 that overturned two centuries of precedent that prohibited patenting of life forms. These events have harnessed the forces of competition to the production of biotechnology in a powerful new way. Studies by Perrin, Hunnings, and Ihnen and by Butler and Marion have documented the dramatic initial impacts of PVPA on the level of private research in plant breeding. There is little doubt that the recent patent decisions are having an even more dramatic impact on private research in other kinds of biotechnology.

The state of our empirical and theoretical understanding of these changes is not very complete, yet there are a number of important issues that would benefit from economic analysis. First, it would be useful to have a better understanding of the size of the explosion in new biotechnology research, and the extent to which it resulted from new property rights versus new fundamental scientific knowledge. Second, the new property rights are as yet ill defined and will not be clarified until after lengthy court cases and probably additional legislation. Economic analysis of changing the appropriability of returns by fine-tuning these property rights would provide useful information in resolving those issues (Perrin). Finally, the international diffusion of these property rights has emerged as a negotiating issue in the current GATT discussions. Economic analysis of research spillovers (along the lines of Evenson and Binswanger) would be useful in determining what is at stake for the U.S. knowledge industry for developing countries and for others that do not currently recognize property rights in biotechnology.

THE EFFECT OF PUBLIC POLICY ON INNOVATION AND ADOPTION

Schultz suggested some time ago that agricultural price policies probably have had a substantial deleterious effect on the payoff from agricultural research. While Alston, Edwards, and Freebairn have considered some theoretical implications of protection policies for the level and distribution of benefits of research, empirical analysis of the importance of price policies on the generation and use of new knowledge in agriculture remains to emerge. If the Schultz hypothesis is correct, such an assessment would be an important contribution of economics to biotechnology research.

A related issue is measurement of the effects of regulatory policy on the payoff from biotechnology research. It seems clear that regulations governing the freedom to test and distribute some biotechnology products are in the public interest. We need some evaluation of the costs of the attendant delays and restrictions and the benefits related to the reduction in measurable or unforeseeable risks.

In summary, the economic issues related to new knowledge in biotechnology are both important and intriguing. The conceptual economic tools need some improvement, and there is a great deal of empirical evidence to be sifted. The pace of change in technology is unprecedented. All these considerations mark this as a fertile field for the attention of agricultural economists.

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