Issues and Developments in Biotechnology: What's an Economist To Do?

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Abstract

The spectacular nature of many of the breakthroughs in biotechnology has generated considerable publicity and has made demands on agricultural economists for *ex ante* assessment of potential impacts This article suggests a research agenda for evaluating the impacts of biotechnology on agricultural production It reviews the regulatory history to identify problems unique to the application of biotechnology to agriculture

Keywords

Biotechology, regulation, production economics

The use of biotechnology will bring about the next major episode of technological change in farming, following the mechanical and chemical innovations of the past The proposed uses of these new techniques, whether to increase milk production or breed pesticide-resistant plants, have generated what seems to be extraordinary and unprecedented publicity This article explores the contentious issues in the use of biotechnology for agriculture and considers what agricultural economists can and cannot do to clarify the choices to be made about new techniques in farming

Use of biotechnologies for agriculture has raised concerns about physical safety and environmental hazards and about socioeconomic impacts of adoption as well The deliberate release of novel genotypes into the uncontrolled environment will be involved in some applications of biotechnology to farming, in contrast to uses in other areas such as medicine At present, the ability of scientists to predict the consequences of such release is limited Yet, debate in the regulatory arena often centers on the level of risk and uncertainty associated with deliberate release Concern about socioeconomic impacts has also been raised The controversy over the ultimate effect of adoption of bovine growth hormone (bGH) on the size and number of dairy farms is a good example (see *11*) [1] The debate leading to the Food Security Act of 1985 clearly reflects the importance of the future structure of American agriculture in that the new biotechnologies will likely be significant in determining the distribution of farms by size category The two sets of issues, physical safety and socioeconomic effects, have frequently become entangled as the courts and regulatory agencies have sought to develop guidelines for research and development of commercial applications of biotechnology To sort through the controversies surrounding biotechnology, both sets of issues must be understood

Agricultural economists can contribute in assessing the impacts of technology on farm size, structure, and production practices, but will have little to say in resolving questions about the new technologies' health and environmental safety The Congress, courts, and regulatory agencies require information on the likely benefits and economic costs of new technologies to make decisions about the advisability of their use, future levels of research funding, design of farm programs, and the like Thus, agricultural economists face a demand for *ex ante* evaluation of new production possibilities Although technology assessment is not a new task, analyses of technological change have usually been done after adoption is complete (for example, Griliches'

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article

work on hybrid corn (9)) However, pressure now exists for analysts to evaluate the impacts of biotechnology with little knowledge about the final form of technological advance Agricultural economists must, therefore, assess the adequacy of theoretical and empirical methods of investigation in trying to make useful contributions to decisionmaking

The discussion that follows explores questions about both the health and environmental safety and socioeconomic impacts of biotechnologies Its purpose is to help agricultural economists understand and anticipate the need for assessment of biotechnologies At the start, we distinguish between biotechnologies as methods of inventing and the products obtained by their application We focus on farm-level use of new technologies, although the implications for input market structure and for post-harvest processing may well be significant Next, we review the regulatory history to highlight contentious health and environmental safety issues We also discuss at some length deliberate release because of its importance in regulatory decisions After exploring issues of physical safety, we consider the conduct of technology assessment by agricultural economists We identify areas in which contributions appear to be possible and appraise the limitations to analysis Finally we make some observations about the roles agricultural economists may usefully play in evaluating biotechnologies for agriculture

Means Versus Ends

In economic analyses, distinguishing between new biotechnologies that represent "methods of inventing" and the products that result from these methods is useful Although these methods of development, such as recombinant DNA, may well raise policy issues associated with environmental safety (release and uncontrolled reproduction of a novel genotype causing environmental damage), agricultural economists will be most concerned with new input and output possibilities the end products of biotechnology research Many, if not most, of the new biotechnologies represent new ways of producing familiar products, such as using plant cell and tissue culture to develop improved crop varieties Other examples include plant regeneration, somatic hybridization, and embryo transfer Few of these procedures will be carried out by farmers, although some may be provided as services by specialized technicians Another important aspect of these techniques is their potential for accelerating the pace of technological change For example, current breeding techniques to produce new varieties may take up to 10 years before a reliable strain is developed With tissue culture, selection for traits is more precise, cutting the time needed in crossing and recrossing

The end products of biotechnologies are usually more interesting to economists concerned with productivity and agricultural structure than are questions raised by the method of inventing These end products may take the form of either inputs to the production process or new possibilities for output One example might be enhanced versions of conventional products, such as cheaper, more effective vaccines or meat animals whose carcasses have lower fat content Altogether new agricultural products represent another category Commercial production of frost-inhibiting bacteria, applicable to fields and orchards, is an example of a new input High-protein feed derived from petroleum using bioengineered enzymes is an example of a new output (but a new input to the livestock sector) Because these new products would substitute for existing ones (the bacteria for smudge pots and the petroleum feed for soybeans), they could cause abrupt changes in agricultural input industries New industries may develop and possibly replace existing industries

The regulatory process has attempted to determine whether the means through which biotechnologies are produced pose hazards to human health and the environment The deliberate release of genetically engineered organisms into the environment and the possibility of their uncontrolled reproduction has generated the most debate The existence or nonexistence of these externalities is a debate to which economists cannot contribute However, other types of regulatory analyses (such as pesticide evaluation) attempt to compare benefits against risks Both means and ends will be of interest to economists when these types of comparisons are made for biotechnology products

Regulation of Biotechnology

The history of the regulation of biotechnologies is short, but stormy A fundamental issue has been biotechnology's definition, which affects the scope of regulation Industry favors a definition that includes "any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses" (6, p 8) Viewed this way, everything man has done to domesticate plants and animals or to make bread or wine can be described as biotechnology So long as new techniques, such as cell fusion, are considered similar to older technologies, no new regulatory issues arise

Dr Alan Goldhammer of the Industrial Biotechnology Association maintains, "It is important at the outset to stress that many of these new biotechnologies are simply improved versions of existing products and as such should not raise significant regulatory issues" (*7*, pp 1-2) Industry would avoid regulation based on the processes used to develop or manufacture new products because that is the point at which all the newer biotechnology products are guaranteed to be different from past products Industry fears that, if biotechnology were perceived as posing new problems, more regulations and regulatory agencies would be demanded

In contrast, the Federal agencies involved in monitoring biotechnology have favored a more specific definition The Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), the National Institutes of Health (NIH), the Occupational Safety and Health Administration (OSHA), and the U S Department of Agriculture (USDA) have all been involved In their view, biotechnologies fall into three categories (1) classical genetic selection or breeding for purposes such as baker's yeast production, conventional fermentation, and vaccine development, (2) the direct *in vitro* modification of genetic material, such as recombinant DNA or gene-splicing, and (3) the use of other novel techniques for modifying the genetic material of living organisms, such as cell fusion and hybridoma technology (*6*, p 8) Regulatory agencies find a distinction useful between classical genetic selection and the newer techniques (described in the last two categories) because such a distinction emphasizes the source of the potential environmental risks

Responsibility for the oversight of federally funded research on genetic engineering originally rested with a committee operating under the auspices of NIH As the field of inquiry was broadened beyond medicine, other agencies became involved by reinterpreting existing legislation on regulatory responsibilities In June 1986, the White House Office of Science and Technology Policy issued rules describing a coordinated framework for the regulatory assessment of biotechnology that formalized many of the previously evolved relationships and responsibilities NIH will continue to monitor research activities, although other agencies are responsible for overseeing specific application USDA will regulate gene-altered animal vaccines, diseases, plant materials, and plant pests USDA will also continue research in these areas EPA has general responsibility for overseeing genetically engineered microbes, but it will share these duties with USDA when agricultural crops are involved FDA is responsible for animal drugs and human health care products OSHA will look after genetically engineered products used in the workplace

Agriculture is likely to pose the thorniest regulatory problems of all the industries affected by biotechnology Public concern over biotechnologies was initially stirred in Cambridge, MA, when citizens feared a laboratory scientist might accidentally allow a gene-altered micro-organism to escape and contaminate the environment In agriculture, release of novel micro-organisms is certain for many biotechnology products Such products are designed so that farmers can release quantities of micro-organisms, attempting to change biological processes to suit the purposes of agricultural production

Regulatory experience is short However, the record does show that the development of agricultural technologies has been successfully contested, based on their potentially adverse environmental impacts Developers of four genetically engineered agricultural products—a swine vaccine, a frost-inhibiting bacteria, a soil organism with insecticidal properties, and a bovine growth hormone—have requested permission for field tests of their products Each product has made news many times as courts have found regulatory procedures inadequate In contrast, four pharmaceutical products involving genetic engineering have been successfully registered with FDA Insulin, human growth hormone, interferon, and a hepatitis vaccine are now produced commercially The advisability of the deliberate release of gene-altered organisms has created a debate unique to agriculture

Biologics Corporation, the manufacturer of a vaccine for the swine virus, pseudorabies, has won, lost, and now regained its USDA registration to sell the product The vaccine is created by gene deletion and is a weakened, but live, form of the pseudorabies virus It was alleged that USDA had not followed its own guidelines for assessment in granting the registration The Foundation on Economic Trends, headed by Jeremy Rifkin, sued, and the registration was temporarily canceled but subsequently reissued Although the Foundation's complaint was filed on the basis of improper regulatory procedure, the real issue centered on the potential hazards from deliberate release of genetically altered organisms In reissuing the license, USDA argued that deleting the single gene prevented the virus from producing an enzyme it required to multiply and spread

Frostban is a bacterium designed to inhibit the formation of frost on plants This gene-deleted product

is identical to the naturally occurring bacteria that inhabit plants, except that it is missing the part of its genetic code that triggers production of an ice-nucleating protein that promotes frost No application for permission to field-test Frostban has yet been successful In 1984, a University of California test was prevented by a court ruling that NIH had illegally given its approval In late 1985, a private company, Advanced Genetic Sciences (AGS), obtained an experimental use permit from EPA EPA subsequently revoked the permit because of questions raised about the experimental procedure In August 1986, University of California scientists again proposed a test of the bacteria, but a temporary restraining order has delayed the test, at least until spring 1987, while an environmental impact statement is prepared Evaluation of the potential risks of releasing a unique organism was at the crux of the debate

Monsanto has developed a soil microbe genetically engineered to have insecticidal properties, but it has also failed to gain EPA approval for experimental field testing This bacterium is altered to carry additional genes, making the organism toxic to some insects The engineered microbe has the toxicity of the insect pathogen, *Bacillus thuringiensis* Berliner, commonly known as Bt Its purpose is to reduce the need for synthetic organic chemicals to control corn rootworm EPA's decision is still pending while more information on the behavior of the altered organism is gathered

Bovine growth hormone (bGH) raises an entirely different set of questions Unlike other agricultural biotechnologies, bGH does not require deliberate release of a genetically engineered organism The development of a process for its industrial manufacture solved the problem of producing large quantities of the substance inexpensively By injecting purchased bGH, dairy farmers can theoretically augment the flow of bGH that dairy cows normally produce If administered at the correct point in the lactation cycle, bGH could markedly increase milk production Because bGH is a naturally occurring substance, its use and release into the environment does not pose the risk of changing ecological processes by introducing a new organism The risks considered by the regulatory process include the potential for damage to dairy cow health and the question as to whether milk or meat products would contain substances harmful to consumers If these risks did exist, controlled use of bGH could probably limit their effects In contrast, the deleterious effects of introducing new organisms are not always controllable Apart from the question of deliberate release, the regulatory issues by bGH have been more like the issues raised by human health products rather than the other agricultural biotechnology products However, concerns over how bGH might affect both the trend toward fewer and larger dairy farms and the costs of farm programs could delay the commercial release

Deliberate Release

The deliberate release of gene-altered organisms raises many of the same problems as use of toxic chemicals how chemicals are changed and where they will be moved, and hazards, exposure, and effects on ecosystems (*15, 16*, p 60) However, the possibility of uncontrolled reproduction of some genetically engineered organisms makes the problem more like one of introducing an exotic species Although many such introductions fail, there have been notable exceptions, including the gypsy moth, starling, and kudzu vine in the United States and the European rabbit in Australia The important questions about introduced exotics are whether they will disrupt any other ecological processes or whether they will pose any health hazards Before these questions are asked, one has to know whether the exotics will survive, and if so, whether they will reproduce To answer these questions and forecast the impact of introducing exotics, biologists have classified exotic species four ways (1) slightly modified forms of resident types, (2) forms that exist naturally in the target environment, but which require continual supplemental support or continual replacement to be sustained, (3) forms that exist naturally elsewhere, but which have not previously reached the target environment, and (4) genuine novelties (*16*, p 59) This classification scheme is useful in analyzing the deliberate or accidental release of genetically engineered organisms because it highlights the problems in forecasting externalities

The three genetically engineered agricultural products that involve release of an organism may be categorized despite little or no actual experience with two of them Frostban is identical to naturally occurring bacteria, except for a deleted gene Because Frostban is produced by gene deletion, the altered organism might be weakened and might need continual support or replacement, as described in category (2) Gene deletion makes the bacteria unable to invade plants through frost damage Hence, Frostban might be unable to compete with natural bacteria in the long run The pseudo-rabies vaccine, also produced through gene deletion, appears to fall into category (2) The weakened form of the virus makes it suitable as a vaccine The

Monsanto soil toxin represents a genuine novelty and belongs in category (4)

The need for regulation of gene-deleted organisms has been debated Some advocates have seen the gene-deleted products as harmless, on the theory that the engineered organisms are weakened and cannot survive because some of the characteristics allowing them to survive—the tools with which they evolved—have been taken away However, geneticist Jonathan King at the Massachusetts Institute of Technology has said "It is a medieval scientific view that a deletion is automatically less risky" (*20*) He argues that deleting a single gene can produce major changes in the biological activity of micro-organisms DNA molecules exist in a delicate balance, with one gene or group of genes modifying the activity of other genes or groups of genes Removing a gene can upset the balance, causing microbes to mutate and multiply, with unforeseen consequences

Although one organization, the Foundation on Economic Trends, has brought many of the suits to halt testing of gene-altered products, the broader scientific community has raised related issues Some scientists have opposed the Administration's new rules on biotechnology that do not subject products created through deletion or alteration of regulator genes to stringent review Liebe Cavalieri of the Sloane-Kettering Institute has called the Administration's position "scientifically undefensible" (*19*) Because of the uses to which biotechnology will be put in agriculture, the issues of deliberate release and of its use in animals and food products will probably remain contentious Without more experience, researchers cannot accurately predict health and environmental impacts However, opposition has so far successfully blocked most experimental field tests

Technology Assessment: A Starting Point

The use of biotechnologies raises a few new issues for assessment by agricultural economists, but mainly reintroduces some old ones The scope of traditional concerns is reflected in a recent study from the Office of Technology Assessment (OTA) Using the OTA work as a starting point, we suggest a broader scope for assessment and identify key issues and methods in the economic analysis of biotechnologies

The OTA study, *Technology, Public Policy, and the Changing Structure of American Agriculture* (*25*), provides a good starting point for analyzing biotechnologies in agriculture It considers the impacts of new informational and biological technologies, which include a wider range of techniques (for example, personal computers and conservation tillage) than the biotechnologies we consider here. OTA's main concern is with anticipated changes in the structure of agriculture, as defined by the number and size distribution of farms

OTA argues that the new technologies will be adopted by well-financed, innovative farmers who are presumed to run the larger farms These farmers will be advantaged either because of their ability to make the initial capital outlays required for adoption or by their superior management skills, which are needed to take full advantage of the new technologies OTA concludes that the future holds a bimodal distribution of very large and very small farms The demise of middle-size farms (identified as the backbone of U S agriculture) can be averted only by public policy intervention that directly targets the endangered farmers Current farm policies are seen to exacerbate, or at least not to retard, this tendency toward resource concentration in agriculture

OTA's conclusions, however, must be viewed with caution The link between farm size and ability or willingness to adopt new technologies is not well documented Cited literature pertains to experience in developing countries or to use of mechanical technologies, neither of which is necessarily relevant to the future of American agriculture (*13*) Even if all farmers were equally willing and able to pay for new technologies, then for large farmers to benefit, most of the technologies would have to exhibit scale bias Although mechanical technologies, such as the large combines adopted since World War II, may have displayed such scale-dependence, it is not clear that the new technologies will

Using the OTA analysis as a starting point, we can identify two important areas for further study First, are only large farmers willing and able to innovate? How does managerial ability vary with size? Will these new technologies really require large initial capital investments? (Even in the OTA study itself, the results are mixed) The structure of the market for these new technologies, particularly the power of nonfarm firms as input suppliers, should also be evaluated (*24*, p 1177) Second, what are the characteristics of the technologies? How can scale-dependence be predicted? Would economies of scale arise out of technical conditions of production or from pecuniary sources? Day has noted the importance of the scale issue in evaluating public research priorities (*2*, p 999)

Further Issues in Biotechnology Assessment

The scope for assessing new biotechnology products goes beyond a consideration of their scale dependence Although evaluation of decisions to invest in research into new technologies would not be a new task for agricultural economists, development and use of biotechnologies may highlight the importance of equity as well as efficiency criteria in project selection (*1*, p 960) The unprecedented nature of the potential environmental impacts of the use of gene-altered organisms in farming will present new research problems Traditional methods for studying innovation will be useful for new biotechnology-based products, although the demand for *ex ante* analysis may create new challenges Finally, considering the financial stress in the agricultural sector, economists must carefully explain profit and output implications of new products and technologies

Research Evaluation

Public and private funding for research ultimately determines what new technologies and products are available to the agricultural community In explaining the outcome of the decisionmaking process, Hayami and Ruttan's induced innovation hypothesis predicts that changes in factor ratios brought on by technological advance will be a function of changes in relative factor prices (*10*) Have the recent innovations of biotechnology been induced in this way? If biotechnologies are land-saving, as Hayami and Ruttan suggest (*10*, p 75), was their development encouraged by the runup in farmland values in the seventies? Does the recent decline in the land market affect the likelihood of adoption of these innovations? Kislev and Peterson have criticized the induced innovation approach for its failure to distinguish between technical change that is external to farming (as occurs in input manufacturing) and change that is internal Distinguishing between the two types of change affects the responsibility one assigns to the agricultural research system for the impacts of technological advance (*12*, p 562)

The induced innovation model implies reliance on market signals to spur appropriate technology development However, the predictive ability of the induced innovation model may be questioned, if society applies criteria other than those embodied in market signals to the selection of new technologies Concern over U S export performance in world markets means that transferability of new production technologies to potential competitors or customers may become a consideration in development Concern over the preservation of farming and rural life, in addition to worries about resource conservation, indicates the importance society may attach to amenities whose values are not well reflected in market prices Bonnen (*1*) has suggested that the role of the social sciences should be expanded when analysts evaluate research supporting innovations in production agriculture More emphasis on institutional and human capital impacts of new technologies would be appropriate However, Shumway has questioned the usefulness of economists' *ex ante* quantifications of research benefits in guiding decisions and has stressed the importance of the individual scientist in problem selection (*23*)

Risk Assessment

The novel nature of some of the products of biotechnology puts a new slant on risk assessment for agriculture The use of biotechnology in agriculture presents potential problems associated with the deliberate release of genetically engineered organisms into the environment The first difficulty in dealing with such a release is encountered when regulations are designed (see *17*) In principle, many of these issues are similar to those associated with externalities in that they involve outcomes not currently valued by the market Questions about the safety of these new products are currently being dealt with by the judicial system Ultimately, tort law stands to be the final arbiter in the event that compensation is sought for damages due to injury from the use of these products (see *22*)

There is no reason why resolution of such questions should be the sole province of the courts or why lawyers should be the principal actors in resolving these issues By broadening their conception of risk assessment, agricultural economists could have an educational role in presenting alternative scenarios of the measurable economic welfare gains and losses to society with and without such new agricultural technologies W D Ruckelshaus, the former EPA administrator, has argued for a broad role for regulatory agencies in evaluating and resolving problems associated with the use of genetically engineered organisms in the open environment (*18*) The potential contributions of economists to such risk management have not yet been identified

Adoption and Production Analyses

A broad area of inquiry concerns adoption and production studies for new technologies Three points are of particular interest here the assessment of the distributional impacts of new technologies, prediction of the likelihood of adopton of new bio-

technology products, and the ability of economic analysis to deal with changes in product quality

The OTA study suggests that the distributional effects of adoption of new agricultural technologies will be more important than ever Concerns about the structure of agriculture have been at the forefront of recent farm and food policy debates Agricultural economists will need to provide decisionmakers with more specific information about the identity of gainers and losers from technological change Researchers working in developing countries (see *21*) have more frequently confronted such equity issues than have those in the United States

To go beyond a tautological separation of farmers into innovators (early adopters) and laggards (late adopters), analysts will have to consider differences in managerial skill, economic circumstance, climate, and resource endowment Such information is crucial to predicting the success of adoption of new technologies that depend heavily on the level and quality of complementary inputs for maximum gain Feder's study of interrelated agricultural innovations (again in a developing country context) is a useful reference (*4*) Several studies have suggested means of evaluating the adoption decisions of farmers *ex ante* Goodwin, Sanders, and de Hollanda use simulation models of farms to evaluate the effect of risk preferences on adoption decisions (*8*) Yassour, Zilberman, and Rausser present a more general framework, allowing new technologies' impacts to be reflected in a variety of stochastic distributions for crop yield (*26*) The immediate problem with this approach to evaluating biotechnologies is often the analyst's ignorance of the nature of yield impacts However, experiment plot data, when available, may fill this void until commercial introduction Flood, McCamley, and Schneeberger have recently used a mean-variance framework to evaluate the congruence between yield test results and farmers' variety adoption decisions (*5*) Lesser, Magrath, and Kalter present a method for *ex ante* projection of adoption rates of bGH (*14*) These analyses demonstrate how the existing methodological framework can be used to evaluate the products of biotechnology

To be useful, *ex ante* analyses will have to be specific to individual technologies or packages of technologies Treating technological change as a homogeneous force (as when it is represented empirically by a time trend) will not help make predictions The challenge will be to anticipate new products as they approach commercial introduction For some products, early warning for economists is provided through the regulatory system For others, a system capable of monitoring products emanating from a broad spectrum of private and public groups worldwide is needed The technology group of USDA's Economic Research Service has begun to consider this issue, investigating how Agricultural Research Service reporting might be used to track emerging technologies The United Nations Industrial Development Organization has initiated a monitoring service as well

Biotechnologies will produce both enhanced versions of existing products as well as completely new ones Economic theory provides a limited framework for dealing with changes in the quality of goods or with the introduction of new goods (this may sometimes be viewed as a continuum rather than as two separate problems) Hedonic analysis may help identify and value characteristics of new or enhanced agricultural products On the supply side, production theory offers no sophisticated way to predict shifts in the production function or in the values of the parameters after technological change As Kislev and Peterson point out, product innovation creates an identification problem because the distinction between changes in input quality and technological change may be arbitrary (*12*, p 564) Separating these issues presents a challenge to empirical estimates of productivity impacts of new biotechnology-derived products

Impacts on Output

Changes in orientation of agricultural research have presented another challenge to the economic analysis of new technologies The old research precept of seeking to have "two blades grow where one grew before" is no longer unanimously held Instead, agricultural research priorities now focus on what is deemed cost-reducing rather than yield-enhancing new technologies To an economist, these changes are two sides of the same coin because both kinds of technological change result in an increase in output, except in the case of perfectly inelastic demand This situation is the analytical consequence of profit maximization The result that technological change fails to increase output and instead increases only profits is never obtained Marginal cost, and so supply curves, always shift downward and to the right with the adoption of such new technologies

In competitive markets free of Government programs and intervention, technological change offers greater profits to early adopters and greater production and concomitant lower prices to consumers However, commodity programs designed to maintain farm prices and income further complicate

technology assessment Predictions of inevitable output increases from technology development are not very appealing to agricultural research administrators in an era of surplus production These scientists must cope with criticism from those who argue that agricultural research exacerbates the contemporary overcapacity problem Given that U S market share and price have declined steadily in recent years, it seems counterintuitive to argue that output must be increased to maintain competitiveness in world markets However, because the prediction of ever-increasing output stems from fundamental assumptions of economic analysis, either the conviction of economists that this result is inevitable should be communicated to policymakers or the method of analysis should be reconsidered

Conclusions

The use of the products of biotechnology in agriculture poses difficult problems for those who develop Federal regulations to ensure environmental health and safety The deliberate release of genetically engineered organisms is a particular area of conflict in risk management Litigation challenging the adequacy of regulatory safeguards can slow or prevent approval for field-testing or commercially selling gene-altered products Predicting the timing of the availability of some products is thereby complicated The number of regulatory agencies involved in evaluating products for agriculture (USDA, EPA, FDA) creates even more problems

The spectacular nature of many breakthroughs in biotechnology has generated considerable publicity and has made demands on agricultural economists for an *ex ante* assessment of the potential impacts Some products developed using these new techniques do present unique problems in the assessment of human health and environmental risk Although some products will represent completely new inputs or outputs, several others will simply be enhanced versions of familiar products In any event, the pace of technological change in agriculture may be accelerated because the new techniques often allow short-cuts in conventional plant and animal breeding and selection

Agricultural economists enter treacherous, but not necessarily uncharted, waters in considering the potential effects of these new technologies Predictive ability, however, may be limited Drucker has argued that such impacts cannot be known in advance and that efforts in that direction only "guarantee full employment to a lot of fifth rate science fiction writers" (*3*, p 54) Nonetheless, the unprecedented rate of change will mean that, if agricultural economists are to have much useful to say about the impacts of new technologies, they will need to do *ex ante* analysis The most urgent informational needs of decisionmakers now appear to place demands on the weakest skills of agricultural economists Evaluations of the risks and benefits of environmental release of genetically engineered organisms and of the institutional and human capital aspects of technological change are required Although the insight gained from more conventional production analyses will be of use, exclusive use of this approach in the future will surely curtail the participation of agricultural economists in decisions governing the choice of biotechnology-based products

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