Staff Paper

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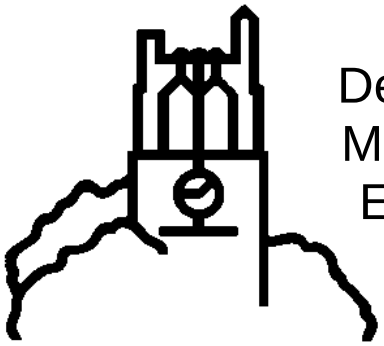

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ECONOMIC AND SOCIAL CONSEQUENCES OF BIOTECHNOLOGY: A SCENARIO ANALYSIS

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by
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Over the years agricultural technology has created remarkable commodity production growth rates and enhanced general economic growth through food production, manufactured goods and trade for most nations. Biotechnology holds the promise of continuing this remarkable record. There is a long list of potential benefits of biotechnology but unfortunately the perceived costs/risks are also many. These concerns have lead to significant consumer reluctance to accept the technology and, in some cases, outright consumer rejection of the technology. To discuss the future of biotechnology, scenario analysis is used to examine the social and economic impact of biotechnology on industrialized and emerging nations. Four scenarios are discussed in detail: biotechnology may be formally or informally banned (Scenario 1), fully accepted (Scenario 2), marketed through strict labeling (Scenario 3), or limited to non-food applications (Scenario 4). Consumer acceptance of this technology will be key to determining which scenario becomes the future for each nation. The likelihood of each scenario is different for each nation, the U.S. will most likely evolve into scenario 2 or 3, while in the EU scenarios 1 or 4 are more likely. Determining the future for emerging nations is extremely complex and dependent on several factors like malnutrition rates, environmental safety and historical trading routes. Each scenario has a major impact on small producers worldwide which ultimately influences the health of rural communities. The analysis indicates that emerging nations are the most sensitive to the timing of decisions being made about the future of biotechnology. If biotechnology becomes a reality, new data will be required to assess the social and economic impact of this technology.

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Economic and Social Consequences of Biotechnology: A Scenario Analysis

Over the years agricultural technology has created remarkable commodity production growth rates and enhanced general economic growth through food production, manufactured goods and trade for most nations. As yet another wave of technological innovation, biotechnology holds the promise of continuing this remarkable record. There is a long list of potential benefits of biotechnology which include, but is not limited to, increased production through reducing impacts of pests, improved storage, enhanced health effects from potential stacked traits that fight resistance and increase nutritional value, and improved environment through reduced pesticide use. Unfortunately, the potential and perceived risks are many as well, including threats to environmental and health safety, the emergence of poor nations as inappropriate technological testing grounds, and the potential for other unintended (and as yet unknown) negative consequences of a dramatically new technology. Collectively, these concerns have lead to significant consumer reluctance to accept the technology and, in some cases, outright consumer rejection of the technology. Less commonly discussed is that biotechnology may have other impacts of concern on the social aspects of food production, historical trade routes, economical size of farms and possibly the number of producers.

To analyze these controversial issues about biotechnology, the paper begins with a description of three key uncertainties–food security, environmental/health impacts, and consumer reaction–that will define the future for biotechnology's use in food applications. Based on these uncertainties, four alternative future scenarios for biotechnology are presented. The probabilities of these various scenarios developing in reality are then examined in the context of both industrialized and emerging nations. The likelihood of the various scenarios, i.e., the likelihood of biotechnology's acceptance or rejection, is dramatically different based on what type of nation is considered. Distributional impacts of these possible futures are then presented with a focus on emerging nations. Finally, the data requirements are defined for properly monitoring the resolution of the uncertainties and the analysis of distributional impacts.

What evolves from the analysis is a complex image of biotechnology's future. For emerging nations especially, the technology offers both immense benefits and extreme risks. Emerging nations may be torn between feeding their populations at home and losing trading partners abroad. Timing may be everything. If the emerging nations wait too long to adopt the technology and it proves beneficial, they may miss income opportunities through trade and may end up importing food products that they should actually be producing and exporting. If they adopt too quickly and the technology proves to have net costs instead of benefits, they may lose both at home and abroad.

Fundamental Uncertainties about Biotechnology's Future

The controversy over biotechnology is driven by a number of key uncertainties. The first uncertainty is whether the growing population of the world can be fed without the emergence of a new "green revolution." Biotechnology has been argued to be this needed new technology. Some population growth projections would clearly argue that this new revolution is needed. Even so, biotechnology may or may not be the needed new technology. However, the slowing of world population growth rates, the emergence of expanding commodity supplies from emerging nations, and the current glut of food commodities worldwide would be counter arguments against this need. Thus it is uncertain whether biotechnology is needed to assure food security.

The second uncertainty is whether biotechnology results in net environmental and health benefits or costs. On the benefits side, biotechnology reduces reliance on agri-chemicals in the food chain and holds open the promise of new beneficial health attributes being engineered into food, e.g., golden rice. On the cost side are the concerns over superweeds, superbugs, loss of beneficial insects or plants, terminator technology, allergic reactions, loss of nutrition, and other unintended environmental and health consequences of a new technology. The argument has been advanced by some that these costs have been overestimated and that "good science" can prove this. Again, it is unclear whether biotechnology will bring about net gains to the environment or human health.

The third uncertainty relevant to the future of biotechnology is the public/consumer reaction to the technology. In reality the first two uncertainties will almost assuredly not be resolved perfectly in one direction or the other, i.e., absolutely needed/absolutely safe or totally unneeded/totally unsafe, the reaction of the public to the likely tradeoff decisions related to biotechnology will have a major impact on the nature of it's adoption. This has already proven to be true. There will likely be perceived differences across the public about the costs and benefits related to either food security or environmental/health impacts. As a result, one part of this uncertainty is whether individuals in a market setting will be allowed to respond individually or instead governments will respond en masse on behalf of the public in the form of broad regulation. Another part of this uncertainty is whether the consumers in the industrialized versus emerging nations may respond differently in how benefits and costs are assessed and traded off.

By their very nature, these three uncertainties cannot be resolved in the short-run. Only the emerging actual changes in population growth, biotechnology impacts on environment and health, and public/consumer reaction can resolve the uncertainties. Unfortunately, decision makers both private and public must make decisions today about whether to continue, expand, or abandon investments in the technology. Without such decisions, the technology may not be available if needed and may not be appropriately managed to mitigate adverse impacts if they emerge.

Four Scenarios for Biotechnology's Future

Based on the techniques of scenario analysis (Schonemaker), four possible futures could emerge based on these uncertainties:

> **Scenario 1: Biotechnology is banned, either formally or informally.** The most direct road to this scenario is that the food security needs do not emerge, but the adverse environmental/health impacts do. The public reaction will be clear and negative in this case, either individually or en masse. A less direct road to this scenario could also emerge. The perceived adverse impacts of biotechnology come to be viewed by the public as a set of risks that are not seen as outweighed by any level of potential benefits. Biotechnology may thus be banned formally by government or informally by consumer choice in the marketplace. The U.S. nuclear experience provides evidence of this less direct path. Although no formal ban exists, public reaction has in effect lead to no new nuclear power facilities being built in the last 20 years.
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> **Scenario 2: Biotechnology becomes fully accepted in the marketplace.** Consumer-oriented biotechnology products become available, and biotechnology follows the pattern of other past agri-food innovations. Again, there are both direct and indirect paths to this scenario. The direct path is that the food security needs do emerge, and biotechnology proves to be safe in meeting

these needs. The public reaction will be clear and positive in this case, either individually or en masse. The indirect path is that the food security need emerges, safety protocols (public and/or private) are developed to allay public concerns, and biotechnology emerges in the court of public opinion as the safest of available alternatives. Either path would result in biotechnology ultimately becoming fully accepted even though the indirect path would have a longer period of controversy before consensus emerged.

Scenario 3: The food system adopts a "three labels" approach to biotechnology. Given the nature of the food security and environmental/health uncertainties, a solution that may evolve and has been adopted by some already, e.g., Japan, is to label all food by its method of production–conventional, biotechnology, and organic. Individual consumers thus choose in the marketplace based on their individual weighing of the risks and benefits. The public reaction is thus allowed to be resolved on an individual basis rather than en masse.

Scenario 4: Biotechnology is used only in non-food applications. Consumers are unwilling to have biotechnology used in food, but would allow commercial or industrial applications, e.g., pharmaceuticals, replacement of industrial chemicals with biologically based alternatives. Based on the recent StarLink experience and other needs to allay public concerns, a system of careful control of biotechnology crops and livestock emerges. Such agricultural products are produced in environmentally-controlled, manufacturing-like facilities. Strict system segregation from food uses is maintained to the public's satisfaction.

The scenario analysis suggests that the third uncertainty–consumer reaction–is critical to determining which future scenario actually occurs. The first two uncertainties will only be resolved over an extended time while the third one can be and is already being played out in the near term. All scenarios are sensitive to timing for all countries but timing is more crucial for emerging nations. The risk of investing today with no guarantee of a future market (domestic or international) would be devastating for emerging nations as would the cost of resolving adverse environmental or health impacts should they develop.

The resolution of the third uncertainty–public/consumer reaction–depends on the completeness and quality of the information that the consumer has for decision making. In essence, the consumer is faced with a classic information problem akin to the market for lemons (Akerlof). The consumer is being asked to purchase a product whose attributes cannot be known at the time of purchase, i.e., the true costs and benefits of biotechnology. The consumer must thus fear opportunism on the part of the seller, i.e., the life sciences industry, who is presumed to have superior private information. The seller has incentives to hide information if it is adverse to the buyer's interests and to share it if in concert with the buyer's interests. However, the buyer cannot know a priori which is true of the information-sharing practices of the seller. The history of the tobacco industry is a case well established in the minds of the consumers as a perfect example of this information problem.

The problem for the consumer is further complicated by the fact that there are many potential "sellers" of information about biotechnology. Governments, environmental groups, the scientific community, non-governmental organizations (NGOs), and food industry firms outside the biotechnology industry also have interests in consumers' decisions about this issue. The consumer must gauge the integrity of each of these information sources.

The critical question relevant to public/consumer reaction becomes: Who has the integrity to interpret the risks and benefits of biotechnology to the general public and the food consumer? Given the information problem posited, the integrity of the messenger will be a key driver of the acceptance or lack of acceptance of biotechnology and thus of the future scenario that emerges. (For an expanded discussion on integrity see Peterson and Weatherspoon.)

Applying Scenarios to Emerging and Industrialized Countries

The future scenario that emerges for biotechnology will depend on consumers' evaluation and ultimate response to the integrity of relevant messengers about technology and the existing risk factors within their respective countries (no major food issues to malnutrition, human, plant and animal diseases, national security, etc.). Consider first the likely differences in the scenarios that may emerge for industrialized nations, such as, North America versus Europe.[2] In North America (particularly within the NAFTA countries), the probability that either Scenario 2 (full acceptance) or Scenario 3 (consumer choice through labeling) will emerge is high. The US has a long history of successful agri-food system monitors with high levels of both perceived and real integrity, e.g., USDA, FDA, EPA, and university scientists. The USDA, FDA, and EPA have given approvals to biotechnology. Canada, much more than Mexico, has a similar system of monitors to the US, and both Canada and Mexico closely follow the lead of the US on these types of issues.

The probability of biotechnology playing a major role in the future of the EU is much lower than in North America. Scenarios 1 (banning of biotechnology) or 4 (limited use to non-food applications) are far more likely to emerge. The EU's government monitors have lost perceived integrity recently due to the way they handled the outbreaks of mad cow disease and foot-and-mouth disease. The highly promotional manner in which biotechnology was introduced in Europe by the life sciences companies also limited the life science companies perceived integrity. Contrarily, the NGOs have vigorously protested biotechnology and have appeared to have influenced policy which has limited the consumption and production of biotech products in the EU. The current movement in Europe to increase food safety will presumably be expanded to the biotechnology area. For example, COLEACP (a liaison committee for EU-ACP horticultural trade) has just received a large contract from the EU to work directly with exporters from emerging nations to make sure that their products have an acceptable level of pesticides. This effort includes training and labs to test in country which will result in transparency and liability throughout the system. This effort can and most likely will be expanded to test for various biotech enhancements in food products (Guichard). Unless risks are reduced and products are put in the market channel that address consumer benefits (cure diseases, bio factories with positive environmental impacts, etc.), the prospect of biotechnology food products being successful in the EU is low. The other option is that the governing bodies of the EU food system regain their influence and decide that biotechnology is critical for the future.

Arguments have been advanced that the development of consumer benefits from biotechnology (as opposed to the agronomic benefits created to date) will in and of itself create consumer acceptance. In effect, this is an argument that the consumer will forget the potential costs and risks in the face of

[2]Hill and Battle provide a useful analysis of the EU-US GMO debate.

enhanced benefits. Now that the public and food consumers are aware of the issues related to biotechnology, it is not very likely that the emergence of new benefits will eliminate the controversy. The balance of benefits and costs may improve in favor of benefits, but consumers will remain skeptical. For the consumers of the industrialized world most especially, the new benefits may have to be extremely valuable to counterbalance the uneasiness over potential risks.

As a second case, consider the differences of reaction across the emerging nations. The future of biotechnology is more complex for these nations. The economies of many of these nations are dependent on the US, EU or Japan for trade. Therefore, local decisions about biotechnology may be heavily influenced by the final market for the product. In sub-Saharan Africa where many nations have historic trading ties with the EU, the leaders in most of these countries would like to reduce their malnutrition rates and increase income from agricultural trade. Such leaders are torn between the potential benefits of biotechnology and the demands of products moving from home markets to the EU. The economic messages remain mixed as to what to do with the technology. Thus far, only South Africa and Kenya have ongoing trials of biotech products in sub-Saharan Africa. Any of the four scenarios for biotechnology could thus emerge in sub-Saharan Africa given the mixed messages that exist there. In contrast, several South American countries have already commercially produced biotech products and are conducting experiments on new products. The export markets for these nations are largely North American based which is arguably pro-biotech. Hence, the South Americans are taking less of a risk relatively than the South Africans and Kenyans who primarily export to the EU.

Predicting the scenarios for the emerging nations is further complicated by the existence of a centrally-planned economy or an authoritarian regime where government is the sole voice on the biotechnology issue. China is a good example where the government has decided that biotechnology is the key to feeding their population. Consumer choice to avoid biotechnology products may not exist in this system. Scenarios 2 (full acceptance) is created by fiat, but may unravel to Scenarios 1 (banning the technology) or 4 (limiting to non-food uses) if subsequent events prove the liabilities rather than the benefits of the technology. In any event, the surprising result is that Chinese consumers are in effect facing the same situation as North American consumers currently, neither can predetermine the presence of biotechnology in their food and thus neither has real choice. North American consumers do have the ability to create Scenario 3 (private choice through labeling) while the Chinese consumers are not likely to have this choice except perhaps when such choice serves the demands of valued export markets.

A third sub-case for the emerging nations exists and has the highest probability in the poorest of the poor countries. In this system there are several key breakdowns in society that may lead to business representatives having the greatest influence on biotechnology's adoption. These key breakdowns include one or more of the following: dysfunctional governments, extremely high food security risk, a fragile environment, and/or abundant health risk. The perceived risks of biotechnology may be lower than the real risks from these breakdowns. A biotechnology company could provide great opportunities to producers, traders and the rural community. An anecdotal example of this comes from South Africa which does not represent the poorest of the poor as a country, however, it is a nation best described as both first and third world. Monsanto created a pilot program (subsidized the cost of buying the seed) for resource poor producers so that they would try Monsanto's BT Cotton (Brink). These producers were reported to have increased their annual profits by $150 on average. Technology adoption becomes driven by real benefits in the face of very high risk. If this example is expanded to a truly destitute country, it is

a possibility that a private business, e.g., Monsanto, could become the sole driver of adoption. Presently, most biotechnology firms do not see ample returns on their investment and thus bypass these nations.

Distributional Impacts of Possible Futures

There are distributional impacts that vary across scenarios. These impacts are more sensitive and critical for emerging nations and deserve special treatment in this section. Focus is placed on small producers and the general economic and social health in these nations. What is not commonly discussed is that biotechnology will strongly influence the social aspects of food production, trade competitiveness, economical size of farms, and the number of producers. For the discussion that follows, scenarios 2 and 3 are considered together because they are relatively similar in regard to distributional impacts while 1 and 4 are considered together because of their similarity to each other and their distinct differences with 2 and 3.

Scenarios 2 & 3

The distributional impacts of scenarios 2 and 3 (biotechnology is fully accepted or there is a three label system) can be both specific to the situation of a particular country and crosscutting for small producers everywhere in the emerging nations. Consider the small producer impacts first. Under either scenario, commodity production will be heavily influenced by biotechnology's presence. Biotechnology R&D has been focused primarily on the largest volume agronomic crops by the large life sciences firms. This trend is expected to continue. The impact this may have on smaller producers worldwide is that they will likely not be able to compete in these markets because this technology is not scale neutral. Small producers may be at a disadvantage for several reasons:

- the specialty crops focused on by small producers have not been the focus of biotechnology research and commercialization. Only universities and government-sponsored research labs usually conduct research on specialty crops;
- biotechnology enhanced inputs are expensive to use and require more working capital;
- although the technology is embedded in seed, the full utilization of the technology requires sophisticated management and marketing practices that create a significant learning and investment curve for small producers;
- marketing options may be limited depending on which scenario evolves and where.

All of these factors indicate that small producers may be exposed to especially high risk if they adopt this technology.

Although Scenario 2 (biotechnology is fully accepted), will likely have a negative impact on small producers of commodity type products, small producers may have a competitive advantage in producing biotech products that are labor intensive or that are unique in their production methods or preservation of identity throughout the system. Products that have medicinal properties would be good examples of where small producers may play a major role.

Timing becomes crucial for emerging nations if scenario 2 becomes reality. The poorest emerging nations need to be in the first wave of adopters and invest in biotechnology to be dominant in the world market and to manipulate the technology to address their local needs (particular pest type, disease resistance, drought resistance, fortification with certain vitamins, etc.). If emerging nations wait too long,

they may miss income opportunities through trade and may ultimately import the products that could have been grown locally. Several South American countries are at the cutting edge of this technology and are competitive in commodity markets. Kenya has conducted trials with biotech crops but has not yet commercially produced anything for market. South Africa has commercially produced corn and cotton, but it is not clear if those products were exported or consumed domestically. If biotechnology is fully accepted, these emerging nations will have an advantage over other emerging nations since the region specific R&D will have been completed by the time the technology is fully accepted by consumers.

Scenario 3, three label system, does allow small producers to be competitive in all three categories: organic, traditionally produced crops and biotech products that are not commodities as discussed under scenario 2. The negative impact this approach could have is that all of the products will have to be tested to make sure that they meet the standards outlined for each category. This is another step that small producers are ill prepared to make. The extra costs of this certification stage may prohibit small producers in poor nations from participating in the formal market.

The positive aspect of scenarios 2 & 3 is that a powerful new technology will be available to address the malnutrition needs in emerging nations. Fortified products and medicinal foods may have the ultimate positive impact on poor rural communities worldwide. Having healthier workers alone may be worth the investment for poor nations. The potential negatives are the social impacts and the environmental and health safety issues. Socially, biotechnology may reduce the number of viable producers in the rural areas and create a large number of displaced people. The rural to urban migration in many emerging nations have overwhelmed the available resources. In sub-Saharan Africa, the economic ramifications are tremendous given that 70-80 percent of the population lives in rural areas and are connected with agriculture. Safety risks associated with the introduction of biotechnology must also be monitored. Who will bear the cost of monitoring, especially in emerging nations? The potential for emerging nations to be the testing ground for some of these new technologies is high. The need for an international monitoring agency may evolve under these scenarios because the individual emerging nations do not have the capital to invest in monitoring at the local level.

Scenarios 1 & 4

The distributional impacts of scenarios 1 and 4 (biotech is banned or limited to non-food applications) are dramatically different from 2 and 3. If the poorest emerging nations were in the first wave of adopters of this technology, this would irreparably harm their producers, particularly the small producers. Producing this technology without a clear indication that there will be a market is extremely risky for these nations. In addition, they are risking all agriculturally related export markets because the world may perceive them as contaminated. Therefore, a nation's timing on when or if to allow biotechnology in the country is crucial.

There are no anticipated positive income impacts on small producers since they will not have access to this cutting edge technology in their production practices. Hence all returns associated with biotechnology for scenario 4 go to the inventors and the special firms that can produce products in a bio-secure environment. At the same time there are no additional negative impacts on small producers or rural areas under either of these scenarios with the exception of those regions that invested early in this technology.

The negative impact of these scenarios is that a tool to address malnutrition needs will not be available in the short run. The positive aspect is that the perceived environmental and health risks associated with this technology are no longer a concern.

Data Needed to Document Impact of Biotechnology on Rural Areas

Given the significant potential benefits and costs of biotechnology, policy makers who want to influence biotechnology's adoption and impacts need to have appropriate data to support decision making and monitoring. Two distinct types of data are needed–data to track the resolution of the uncertainties surrounding the technology and data to document the distributional impacts.

The uncertainties defined earlier–food security needs, biotechnology benefits and costs, and consumer reaction–each demand somewhat different data to monitor how the uncertainty gets resolved over time. The need for biotechnology to contribute to food security will depend upon trends in population growth, demographics, commodity and food production capacity, import/export conditions, and the emergence of non-biotechnology alternatives to improve yields and overall production. To the extent that population pressures ease and alternative production develops, biotechnology becomes more expendable. Conversely, the more population pressures mount and alternatives fail to materialize, biotechnology becomes more necessary whatever the costs. Biotechnology's ratio of benefits to costs will depend most heavily upon whether the downside risks to environment and health actually emerge. Therefore, monitoring of a variety of environmental and health impacts becomes critical, including (but not limited to) changes in beneficial and pest insect populations, biotechnology-induced changes in quantity, quality, and productivity of crops and livestock, changes in bio-diversity, and changes in health among consuming groups. Monitoring the continuing scientific research on the benefits and costs of biotechnology will also be needed. Finally, tracking consumer reaction to biotechnology-based products becomes critical to making marketing, production, and distribution decisions.

All of these data are equally relevant to industrialized and emerging nations. Unfortunately, the emerging nations will have far less capacity to create and monitor the necessary information. From a practical perspective, they may become dependent on interpolating information from experiences in the industrialized world to support their own local decision making. This dependence will create concerns in its own right. One option to alleviate this concern would be to develop an international monitoring agency so that standards are consistent worldwide and the costs of such a system are more broadly shared.

To monitor the distributional impacts of biotechnology, data focused specifically on rural areas of the emerging nations will be critical. Such data would include (but not be limited to): (1) changes in rural population size and distribution, (2) economic activity, including agriculturally related value-added activities, (3) size of an economically viable farm, including minimum effective scale per crop, (4) types of crops produced by method of production (biotechnology enhanced, traditionally produced, and organically produced), location, and size of operation, (5) percent of product actually sold versus personal consumption, (6) percent consumed domestically versus sold globally, (7) commodity and product flows by market channel into formal or informal markets, and (8) tracking of rural incomes per capita. Base-line as well as time series data would be needed to accomplish the monitoring task. Again,

this information system would impose heavy costs on emerging nations unless international agencies step forward to help.

The information base required to monitor either the path of the uncertainties or the distributional impacts would need to be carefully studied to assure that the appropriate data is collected and the appropriate analysis techniques are used for decision making.

Summary and Conclusion

Three key uncertainties–the real need for biotechnology to assure food security, biotechnology's real balance of benefits and costs, and public/consumer acceptance of the technology–give rise to four scenarios for biotechnology's future. The technology may be formally or informally banned (Scenario 1), become fully accepted (Scenario 2), move to market through strict labeling (Scenario 3), or limited to non-food applications (Scenario 4). Consumer acceptance of this technology will be key to determining which scenario becomes the future for each nation. The likelihood of each scenario is different for each nation, the U.S. will most likely evolve into scenario 2 or 3, while in the EU scenarios 1 or 4 are more likely. Determining the future for emerging nations is extremely complex and dependent on several risk factors, e.g., malnutrition rates and historical trading routes.

The future of biotechnology is complex. This analysis shows only four of the infinite options each nation can take in terms of accepting or rejection biotechnology for food consumption. The scenarios suggest that emerging nations are more sensitive to the timing of making this decision since most of these economies are directly connected to the US, EU or Japan, all of which may choose a different future for biotechnology.

Lastly, the impact this technology may have on small producers and rural areas needs further study. This analysis suggests that major changes will occur if this technology is virtually accepted. Small producers are ill prepared for a future where biotechnology is fully accepted. Additional data is required to capture the impacts this technology will have on small producers, rural areas and poor nations.

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